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# REPORT

OF THE

# GEOLOGICAL EXPLORATION OF THE FORTIETH PARALLEL

MADE

BY ORDER OF THE SECRETARY OF WAR ACCORDING TO ACTS OF CONGRESS OF MARCH 2, 1867, AND MARCH 3, 1869,

UNDER THE DIRECTION OF

BRIG. AND BVT. MAJOR GENERAL A. A. HUMPHREYS,

CHIEF OF ENGINEERS,

BY

CLARENCE KING,

U. S. GEOLOGIST.

# VOLUME III.


SIGNALS

UNITED STATES GEOLOGICAL EXPLORATION OF THE FORTIETH PARALLEL.
CLARENCE KING, GEOLOGIST-IN-CHARGE.

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# MINING INDUSTRY

BY

JAMES D. HAGUE

WITH GEOLOGICAL CONTRIBUTIONS

BY

CLARENCE KING.

SUBMITTED TO THE CHIEF OF ENGINEERS AND PUBLISHED BY ORDER OF THE SECRETARY OF WAR UNDER AUTHORITY OF CONGRESS.

ILLUSTRATED BY XXXVII PLATES AND ACCOMPANYING ATLAS.

WASHINGTON.
GOVERNMENT PRINTING OFFICE.
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# NOTE.

The following reports will constitute the series of the Geological Exploration of the Fortieth Parallel:

Volume I. Systematic Geology.

Volume II. Descriptive Geology.

Volume III. Mining Industry.

Volume IV. Zoölogy and Paleontology.

Volume V. Botany.

The present, or Volume III, has been first prepared and published, because its subject, Mining Industry, is most directly applicable to the material development of that great extent of mountain territory opened up by the Pacific Railroad.

The other volumes will be pressed to completion with all possible rapidity. The Atlas of Topographical and Geological maps, necessarily the latest of the publication, will be issued in 1871.

CLARENCE KING,
*U. S. Geologist in charge.*

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The Plates illustrating this volume, as well as those of the accompanying Atlas, were engraved and printed by JULIUS BIEN, of New York.

## LIST OF ACCOMPANYING ATLAS-PLATES.

OFFICE OF THE U. S. GEOLOGICAL EXPLORATION
OF THE FORTIETH PARALLEL.

GENERAL: On March 21, 1867, I had the honor of receiving your letter appointing me Geologist in Charge of the Geological Exploration of the Fortieth Parallel, and defining my duties. I was therein directed to investigate the mining regions adjacent to the 40th parallel.

With a view most completely to accomplish this work, I detailed the first geological assistant of my corps, Mr. James D. Hague, instructing him to devote his time to the study of the engineering and economy of those mining districts in Nevada and Colorado which afford the most instructive results, and produce the largest yield of the precious metals.

Mr. Hague brought to this grave task education and an ample practical experience. In my belief he has achieved a thorough survey of his subject, and upon the title page of the volume herewith submitted, I have given his name its merited prominence.

Assistant Arnold Hague adds a paper on the "Chemistry of the Washoe Silver Process," and one on the "Geology of the White Pine Mining District."

Assistant S. F. Emmons presents an account of the "Geology of the Toyabe Range," a region well known as containing the silver districts of Reese River.

"The Geological Distribution of Mining Districts," "The Comstock Lode," and the "Green River Coal Basin," are the subjects upon which I myself have been able to contribute chapters.

In transmitting the present or Volume III on Mining Industry, permit me to express the hope that it may realize your expectation and be thought to deserve the generous facilities you have placed at our command.

I am, General, very respectfully, your obedient servant,

CLARENCE KING,
*Geologist in Charge.*

Major General A. A. HUMPHREYS,
*Commanding Corps of Engineers,*
*Washington, D. C.*

# CHAPTER I.

## MINING DISTRICTS.

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### THEIR DISTRIBUTION AND GEOLOGICAL MODE OF OCCURRENCE.

West of the hundredth meridian, and bordering the Pacific Ocean from Southern Mexico to the Arctic Sea, stretches a series of mountain chains and elevated plateaus. From a width of four hundred miles on the Mexican line, it rapidly widens to the north, reaching its greatest expansion on the fortieth parallel, where the actual mountain zone is over one thousand miles wide. From this point it again narrows toward the north, diminishing to four hundred miles upon the northwest boundary line.

The central portion of this area is embraced under the general name of the Great Basin. This term, first applied by Frémont, was intended only to cover a depressed region whose streams never reached the ocean; but it has gradually been widened to include all that barren middle ground between the California mountains and the Rocky system.

The Great Basin is walled upon the west by the Sierra Nevada Range. Its eastern boundary is the Wahsatch Chain. A section across the five hundred miles of intervening country, along the fortieth parallel, shows a rapid descent from the Sierra summit, whose elevation at this point is about ten thousand feet, to a depressed zone of country which skirts the great range for a thousand miles and spreads out to the east in comparatively level deserts, its surface here and there interrupted by abrupt chains of mountains. From this area of desert lowland, averaging in altitude about four thousand feet above sea-level, the country gradually ascends to the eastward, the surface being occupied by a succession of meridional ranges separated by trough-like valleys. Where the fortieth parallel intersects the hundred and sixteenth meridian of west longitude the rise culminates, and passing thence eastward the general profile of the plateau sinks gradually to a second belt of depressed plains, whose aridity rivals

those of the Nevada Basin. The desert basin of Utah is still further suggestive of Nevada, since the lofty Wahsatch rises abruptly from its level, scored by sharp cañons, closely resembling the eroded front of the Sierra. The average altitude of the entire system of parallel ranges which trace themselves from north to south across the Great Basin is not far from nine thousand feet. The plains, from a level of four thousand feet, which is about the height of the basins of Nevada and Utah, rise to a mean elevation of six thousand feet in the middle of the system.

If a circle be traced from this central point, latitude forty and longitude one hundred and sixteen, with a radius of two hundred and fifty miles, the circumference will be found to mark a continuous chain of depressions. The middle plateau of Nevada is, then, an important center of elevation and of drainage.

The depressions of the ring are dreary reaches of desert where fields of sand alternate with alkaline plains, where, in the brilliant dry air, the eye may range over expanses of desolate lowland, naked and devoid of all vegetation except those blighted-looking forms of life, the sages, which rather intensify than relieve the deathly aspect of the scene. The central plateau region is somewhat more favored; occasional grassy valleys interrupt the sage plains, and the mountains are less sterile and forbidding. Trees, which were almost wholly absent in the lowland, occur on the loftier ranges; and, near the perpetual snow, which here and there caps the higher summits, an extraordinary fertility is developed.

A glance at any physical map of this region shows a general parallelism of ridges with a prevailing northwest trend. The materials of this immense mountain area are infinitely varied, ranging from the earliest to the most recent deposits, and embracing almost all known species of sedimentary and eruptive products. The greater part of the rock is a series of conformably stratified beds, reaching from the early Azoic up to the late Jurassic period, when these level beds were compressed into vast mountain corrugations and elevated above the sea in a general, wide, and high plateau. Accompanying the upheaval and crumpling of this great oceanic family, and bursting from its fractured folds, are important masses of granite, penetrating the axes of the flexures and breaking through lateral fissures. Quartz-porphyries, felsite

rocks, and, notably, syenitic granite, with occasional occurrences of granulite and greisen, accompany the ejections of granite.

The date of this orographical period is assigned to the late Jurassic, on grounds which will be found fully discussed in the first volume of the present series. It is but just, however, to state here that the foundation of this important discovery in geological dynamics was laid by Professor J. D. Whitney, who early pointed out that the Sierra Nevada was folded after the Lias and prior to the Cretaceous, whose strata of sand and clay rocks repose unconformably upon the upturned and metamorphosed mass of Jurassic slates.

This Exploration has demonstrated that all the parallel ranges of the Great Basin, including the chain of the Wahsatch, its eastern wall, belong to the same system of upheaval, and that, while the Pacific built upon the western base of the Sierras those fringing deposits of sand and clay which thickened through the undisturbed period of the Cretaceous and a wide range of the Tertiary, the Atlantic, or, more exactly, that ocean which covered the Mississippi Basin, beat upon the east flank of the Wahsatch and laid down a series of Cretaceous and Tertiary strata, exactly corresponding with the coast deposits of the Pacific.

At length, after accumulating to an extraordinary thickness, these outlying and later shore-beds, subsequently to the Miocene, were themselves folded into mountains parallel and outside of the earlier system.

As granites accompanied the upheaval of the earlier stratified group, so volcanic rocks have poured out from ruptures of the second mountain uplift. From the crests of the ranges, from the fissured bottom of the Pacific Ocean, from innumerable vents over the whole area of the western mountain system, there burst forth a series of volcanic eruptions which in many instances have overflowed and completely masked the earlier ranges, and in others have filled old depressions, building everywhere immense piles of lava mountains, and lifting here and there volcanic cones of the most impressive order.

Long prior to the deposition of the great Palæozoic beds, a limited group of chains, composed of granites with crystalline schists and interstratified layers of specular iron, was lifted in Arizona and probably over a considerable area of North Central Mexico. Later than the main Tertiary moun-

tain building, which resulted in the Pacific Coast Ranges and the important chains east of the Wahsatch, a final series of disturbances has taken place. But neither are these earliest nor latest dynamical epochs of so considerable geographical importance, nor are they so closely connected with the objects of this volume, as to merit more than this passing allusion.

Unfortunately, no general map of the topography of the far west is sufficiently accurate in detail to serve as a satisfactory basis for a study of the intricate and extended problem of mountain geology. The Warren map of the United States Engineer Department, by far the fullest and most reliable authority extant, is sufficient to illustrate the larger outlines of topography. A section of this valuable map is given in Atlas-Plate I, including the main central region of the Great Basin, with a part of the coast system of California and the outlying chains of the Rocky Mountains.

This Exploration has been confined to a belt one hundred miles from north to south, bordering the fortieth parallel, upon which line the mountains reach their widest expansion. It has extended from east to west between the meridians of one hundred and nine and one hundred and twenty, as a continuous survey, and has gone outside this belt to examine certain important mining districts.

The whole field of labor undertaken by the corps is shown upon Atlas-Plate I; and all the more productive mining localities, embraced within its observation, are indicated by red lines.

A brief study of this map will teach the one great and prominent law of arrangement of Cordillera mountain chains, namely, that they trend from north to south, or northwest to southeast—in other words, longitudinally with the main axis of the whole system of elevation. In strict subordination to this longitudinal direction of ranges are grouped all the structural features of local geology. The average strike of the great areas of upturned strata is generally with the meridian. All the larger outbursts of granitic rocks conform to it as well, since their vents are most commonly the axial lines of actual folds; and, lastly, when the Tertiary uplift occurred, its ranges bordered the older mountains in parallelism, and the volumes of lavas accompanying it found exit through longitudinal vents, and either built themselves up along the ancient lines of structure, or, through new fissures, piled up chains of volcanoes conforming in trend with the general north and south plan.

Over the whole Cordilleras are found localities of the precious metals; and it is not surprising to observe that, following its leading structural idea, they appear to arrange themselves in parallel, longitudinal zones.

This zonal parallelism was first indicated by Professor William P. Blake, in a note in his "Catalogue of California Minerals." It is obviously true, as he has indicated, and it is probable that the idea could be carried much further than he has done. The Pacific Coast Ranges, upon the west, carry quicksilver, tin, and chromic iron. The next belt is that of the Sierra Nevada and Oregon Cascades, which, upon their west slope, bear two zones, a foot-hill chain of copper mines, and a middle line of gold deposits. These gold veins and the resultant placer mines extend far into Alaska, characterized by the occurrence of gold in quartz, by a small amount of that metal which is entangled in iron sulphurets, and by occupying splits in the upturned metamorphic strata of the Jurassic age. Lying to the east of this zone, along the east base of the Sierras, and stretching southward into Mexico, is a chain of silver mines, containing comparatively little base metal, and frequently included in volcanic rocks.

Through Middle Mexico, Arizona, Middle Nevada, and Central Idaho, is another line of silver mines, mineralized with complicated association of the base metals, and more often occurring in older rocks. Through New Mexico, Utah, and Western Montana, lies another zone of argentiferous galena lodes. To the east, again, the New Mexico, Colorado, Wyoming, and Montana gold belt is an extremely well defined and continuous chain of deposits.

In the history of the entire Cordillera there are, then, two periods of orographical disturbance which have been accompanied by the rending of mountain chains and the ejection of igneous rocks. Such periods as these, of course, afford the conditions of solfataric action and the consequent formation of metal-bearing lodes. That period which culminated in the Jurassic, produced over the entire system a most profound disturbance, and is, in all probability, the dating point of a large class of lodes. To the second, or Tertiary period, may be definitely assigned those mineral veins which traverse the early volcanic rocks.

These two periods have produced two types of metalliferous lodes. First; those veins which are wholly inclosed in the granites, or in the more

or less metamorphosed strata of that series which extends, with perfect conformity, from the Azoic up to the Jurassic. The latter are generally found occupying planes of stratification or jointings developed by metamorphism; and although they closely conform in dip and strike to the country rock, the clay selvages and striated surfaces of the quartz, together with a usually unbroken continuity downward, seem to indicate an origin similar to true fissure veins. Of this type are, prominently, the gold veins of California.

The districts embracing what are known as the Humboldt mines are located upon two parallel ranges, formed almost wholly of folded strata of the Triassic age. The veins either occupy planes of stratification or arrange themselves along prominent jointing planes, induced by the disturbances of upheaval and metamorphism.

The districts of Reese River occur, first, in a large mass of granite, accompanying a mountain fold; and, secondly, are found lying in the metamorphic rocks of the Carboniferous in positions similar to those of Humboldt. The celebrated White Pine district, whose mineral deposits are inclosed conformably between strata of Devonian limestone, is a prominent example of the groups comprised wholly within the ancient rocks.

The discovery of the geological horizon of these limestones by Professor Meek is of interest, since it proves them to be among the oldest known silver-bearing rocks in either of the Americas. The mode of occurrence and distribution of the mining districts of Colorado are somewhat unique, and will be so fully treated of in the succeeding chapters by Mr. J. D. Hague, that the writer prefers to make no comments upon them here. In general they belong to the ancient type.

The second type belongs to the second or Tertiary orographical period, and finds its origin in the disturbances of the volcanic ejection. While the fires of the lava period were still burning, and where the deeply riven rocks of the earliest volcanic outflows were repeatedly broken through by subsequent eruptions, and where torrents of water poured down the hill slopes and everywhere penetrated the fissured rocks and came in contact with intensely heated material, there were present all the elements of vein formation. That these conditions actually existed is a matter of every-day geological proof. The lodes of this type are either wholly, or in part, inclosed in volcanic rocks.

Many important veins of Mexico, several of those which border upon the Colorado River within the United States, and, in general, that zone which lies along the eastern base of the Sierra Nevada, are members of this family, as is clearly proven by the fact that they are either wholly, or in part, cased by volcanic rocks. The most prominent example of this type, within the limits of this exploration, is the Washoe district, whose remarkable Comstock lode, although in one place indistinctly touching the ancient formations, yet, as will hereafter be seen, is chiefly inclosed by a modern volcanic rock, and evidently owes its origin to the later disturbances. The Owyhee district, in Central Idaho, occurs upon the crest of a granite mountain chain, which has been intersected by a series of volcanic dikes, ranging from the earliest propylite to the most recent basalt. From the peculiar association of the mineral veins with these dikes, and the manner in which they intersect each other, it is obvious that the quartz lodes belong to the Tertiary period.

From these few but important general facts, it will be seen that by far the greater number of metalliferous lodes occur either in the stratified metamorphic rocks or in those ancient eruptive rocks, which date from the period of Jurassic upheaval; yet very important, and, perhaps, more wonderfully productive, have been those silver lodes which lie wholly in the recent volcanic formations. It is evident from a careful study of the ranges that much of the dislocation and general mountain disturbance was occasioned by the Tertiary upheavals. How far the veins which lie wholly in the older rocks belong to this second disturbance it is impossible to say. In some instances it is evident that the veins themselves have been twisted and disturbed together with the strata; in others it seems most probable that the whole fissure and solfatara were induced by the latest movement. In the present state of knowledge, it is impossible accurately to classify and catalogue the age of the fissures themselves. In almost all cases in which mineral districts are described in this volume, the age of the inclosing rocks is clearly laid before the reader, but data are frequently wanting as to the age of the formation of the fissure. In a majority of cases the evidence tends to the belief that the veins belong to the Jurassic period; and yet it should be borne in mind that wherever the more recent strata have been formed from the detrital materials of the older, we look in vain for the ore-bearing pebbles. The writer is not aware that even in the

broad Tertiaries which fringe the west base of the Sierra Nevada, any auriferous pebbles have been found; yet, at the same time, the Jurassic origin of these veins is proven from other data, as will be seen from the reports of Professor Whitney. The fact, then, of the absence of the ore-bearing pebbles from the later strata is only negative evidence, and cannot weigh greatly against the probable Jurassic age of very many mineral deposits. So far as we now know, no metallic veins occur in the sedimentary formations of the Tertiary period, east of the Wahsatch Mountains; whereas the remarkable metamorphism which has occurred during that period in the Coast Ranges, near San Francisco Bay, has developed extraordinary deposits of quicksilver and chromic iron.

The metallic minerals have, then, in obedience to the prevailing rule of longitudinal structure, arranged themselves in parallel zones, which extend from north to south over great areas. In the history of the Cordillera, two prominent epochs of mountain building have taken place, each accompanied by the ejection of igneous rock with metamorphism and solfataras, and, lastly, with the formation of great numbers of metal-bearing lodes. The lodes belonging to the Jurassic age occur chiefly inclosed between strata ranging from that date down into the Devonian, along the planes of deposition or the jointing planes developed by metamorphism and pressure, or, lastly, in the igneous rocks of the granitic family which accompanied the Jurassic disturbance.

The veins of the second type, which belong to the Tertiary period, are found inclosed either in part or in whole within the volcanic rocks. Their position in that family is among the earlier members, never, so far as is now known, either penetrating the trachyte or basalt. While the greater number of veins probably belong to the first type, some of the most brilliant examples of metal lodes have occurred as members of the second type.

It is a noteworthy fact that of the series of conformable strata forming the main central mountain masses, not less than six, and perhaps as much as ten thousand feet are the true coal measures of the Carboniferous. This Exploration has demonstrated their continuity over a wide area. They were, however, deposited in the quiet depths of an ocean, and, consequently, have no traces of the beds of coal which characterize them whenever laid down near the water level. The fossils they contain are chiefly marine mollusks,

although, in one instance, a relic of land vegetation is imbedded with them. We look in vain for any evidences of shallow areas; the whole Carboniferous zone is of fine homogeneous materials, deposited with rare regularity, and without a single evidence of cross-currents, or any appearance of wave-marks.

The two bordering systems contain, however, near the upper limits of the Cretaceous and upward into the Tertiary, important beds of coal. The exact age of this coal has been long discussed, authorities differing. It seems probable, from the discoveries of this Exploration, that both parties are grounded in fact.

Of the Cretaceous origin of the California beds, Professor J. D. Whitney is certain, and the writer has, as will be seen in a later chapter, shown the same age for those beds which are included in the sandstones along the east base of the Wahsatch Chain. Continuing eastward, the strata, still remaining conformable, undergo a change of character. The marine fossils disappear, to be replaced, first, by brackish-water types of doubtful affinities, and finally by clearly recognized fresh-water Tertiary forms, the coal beds continuing at intervals through this transition period. Dr. Hayden is unquestionably right in assigning a Tertiary age to many of the beds east of Green River; so that, as is often the case, the contestants for both views are correct in their data.

# CHAPTER II.

## THE COMSTOCK LODE.



## SECTION I.

### GEOLOGY OF THE WASHOE MINING DISTRICT.

VIRGINIA RANGE.—Among the most continuous and well defined of those chains which diverge from the northwest trend of the Sierra Nevada to a nearly meridional course is the Virginia Range.

Leaving the Sierra where its eastern slope descends boldly to the plains of the Great Basin, in latitude 38° 8′, it stretches due north for a hundred and fifty miles, terminating in terraced hills which sink under the quarternary desert-beds of Mud Lake Valley. Its average breadth is about eighteen miles, though no accurate mean width can be arrived at because of very unusual variety of form. Three considerable rivers, from the snow drainage of the Sierra, cut transversely through it, making cañon passes which sink three or four thousand feet below the general summit line. These are the Walker, Carson and Truckee. Groups of comparatively low hills spread out from either flank, those on the west not unfrequently connecting with the Sierra.

The drainage which flows down its west side is gathered in a series of ponds and small streams, finding its way at last into one of the three rivers, and finally flowing through their cañons to the sinking lakes on the east side.

Rising from a base of 4,500 feet above sea-level, its line of summit peaks reaches an average of 7,500 and a culmination here and there of nearly 9,000.

Although, generally, rising near the middle of the range, these summits, from geological accidents, deviate to one or the other side, and overhang the valley plains in lofty precipitous peaks. The range may be considered as based on an inclined plain, for there is a gradual slope from the foot-hills of the Sierra to the bottom of the depressed basin, lying east of the mountains. The valleys to the west are never continuous for any great distance, but are divided by spurs of the Sierra which invade them from the one side, and by low volcanic groups which push out from the other. Receiving the drainage of both mountains a considerable fertility is developed; not enough, it is true, to banish the monotone of olive-gray desert vegetation, but sufficient to produce fine grass fields and valuable grain farms. Eastward, the Virginia Range overhangs the most depressed and dreary part of Nevada. From its summit may be seen the sinks and alkaline lakes, the vast stretches of blank, naked desert, varied by beds of dazzling saline efflorescence whence, in the blazing heat, columns of parched air whirl upward, laden with acrid dust and drifting sand. It is almost impossible to conceive a scene of more stern, desolate grandeur than may be viewed from the Virginia crest. The Sierra Nevada rises high against the west, its summit snow-capped, and its flank shaded by a forest of dark-green pines which grow thinner in descending toward the plain, and at the foot-hills perish of drought. In the east, beyond the chain of sinking lakes, rise rank beyond rank of parallel ranges, strange in form and unusually strong and bright in color. Threads of green skirt the water-courses, but the general tone is red-brown of rocky mountain-slopes and olive-gray of desert vegetation, startlingly relieved by caps of snow and fields of snow-like alkali.

General Geology.—A very general sketch of the larger relations of all Great Basin ranges to the Cordillera System has been given in a previous chapter. It is only necessary for the comprehension of Washoe geology to indicate the outlines of closely contiguous hills.

Both the Sierra and Desert ranges are composed, first, of crumpled and uplifted strata, from the late Jurassic down to the Azoic period; secondly, of ancient eruptive rocks, which accompany the Jurassic upheaval; and, thirdly,

of modern eruptive rocks, belonging to the volcanic family, and ranging in date, probably, from as early as the late Miocene up to the Glacial period. Folds of more or less complexity, twisted and warped by longitudinal forces, often compressed into a series of zigzags, sometimes masked by outbursts of granite, syenitic granite or syenite, and, lastly, built upon by or frequently buried beneath immense accumulations of volcanic material: these are the characteristic features of mountain chains. They are usually meridional and parallel, and separated by valleys which are filled to a general level by Quarternary detritus, the result of erosion from the early Cretaceous period down to the present time. The east slope of the Sierras, directly facing the Washoe region, is, in brief, a relic of metamorphic schists and slates, skirting the foot-hills and resting at high east and west angles against the great granite body which, for many miles to the southward, forms not only the summit but the main mass of the range. Rising through the granite, and forming an eastern summit, is a lofty mass of sanidin-trachyte, of a dull chocolate color, and only remarkable for the beautifully regular prisms of black mica which intersect it. The ridge known as the Washoe Mountains is of this trachyte; its culminating height, Washoe Peak, lies directly west and across the valley from Mount Davidson, the center and summit of the Virginia mining region.

Little can be learned of the ancient structure of the Virginia Range, for eight-tenths of its mass are made up of volcanic rocks. Only at rare intervals, where deep erosion lays bare the original range, or where its hard summits have been lifted above the volcanic flows, is there any clue to the materials or position of the ancient chain. Mount Davidson is one of these relics, being composed of syenite. Inclined against the base of this mass, and in the bottoms of ravines, eroded in the volcanic material, occur considerable hills ot metamorphic rocks, schists, limestones, graphitic shales, and slates. Southward, in the cañon of the Carson, and in the ravines of the Pine Nut hills, are uplifted slates and carbonaceous shales associated with irregular limestone beds, the whole surrounded and limited by volcanic (andesitic) rocks. Still further southward, the crest ridge of the Pine Nut region, which is a continuation of the Virginia Range, is syenitic granite, forming high rugged crags, of an extremely picturesque aspect. Every analogy would point to the belief that these relics of aqueous rocks, and the granitic masses accompanying them, are

identical with the similar rocks which predominate in the majority of Cordillera ranges; but we have positive proof of this in the fact that in Eldorado cañon, one of the ravines of the Pine Nut hills, Professor Whitney has found Triassic fossils.

With few exceptions, then, the range is built up by successive outpourings of volcanic rocks, whose mode of occurrence, although simple and evident in general plan, is very complicated in detail.

In résumé, it may be said that this range is one of the old Jurassic folds of stratified rocks, through whose fissures granite and syenite have obtruded; that after a very long period of comparative repose, from the early Cretaceous to the late Tertiary, the old range was riven in innumerable crevices and deluged by floods of volcanic rocks, which have buried nearly all its older mass, and entirely changed its topography. During this period of vulcanism the present valleys were in great part filled with fresh water lakes; and near the base of the Virginia Range we have evidence, in the tufa deposits, that a considerable quantity of volcanic material was both ejected under water and flowed down into it. Water penetrating the fissured range and meeting melted rock gave rise to the solfataras and hot springs, whose traces are everywhere apparent. Following this age of lava and steam eruptions came the Glacial epoch, with its sequel of torrents and floods, and finally a great desiccating period, introducing our present condition.

Atlas-Plate II is a geological and topographical map of the region immediately about the Comstock lode, on a horizontal scale of three inches to one mile, and constructed with grade curves of fifty feet vertical interval. The distance embraced from north to south is a trifle less than six miles, and from east to west a little more than four miles. This ground was chosen with the purpose of illustrating the geological mode of occurrence of the Comstock lode. It is, therefore, almost wholly in the eastern slope of the range, extending longitudinally a sufficient distance to embrace the silver lode and such developments of rocks as affect it, with a breadth from east to west which includes the summit peaks, and reaches in one place to the eastern base of the range. It would have been interesting to print, also, a full map of the range, but a wider area would have introduced no facts which are not sufficiently well shown in the limits of Atlas-Plate II. The topographical survey

was made and the map drawn by Mr. James T. Gardner, first topographical assistant.

Before proceeding to the study of the detailed geology of the district a word of reference is due to those who have preceded this Exploration in investigating the Comstock lode and its surroundings.

Ferdinand Baron Richthofen has published a pamphlet entitled "The Comstock Lode: Its Character, and the Probable Mode of its Continuance in Depth. San Francisco, November 22, 1865."

This paper, by far the most important contribution to our knowledge of the region, presents a brief sketch of the local geology and a quite detailed account of the underground developments at that time. In describing it to-day with all the light of four years additional work, the writer is unable to confirm some of Richthofen's views, or rather predictions, as to the mode of the continuance of the vein in depth, but this should in nowise detract from the value of his instructive paper. A comparison of the two investigations will show exactly how far the present study accords with Richthofen and how gravely it is opposed in some points.

Mr. J. Ross Browne and Mr. R. W. Raymond, United States mining commissioners, and Mr. R. H. Stretch, State mineralogist of Nevada, have also given to the public their observations in official reports, but since they are chiefly confined to a study of the economy and engineering of mines, they will be more fully mentioned in the mining engineering report of Mr. J. D. Hague, which immediately follows this chapter.

The area represented upon Atlas-Plate II, lies wholly upon the eastern slope of the Virginia Range. In the northwest corner is seen a flat, plateau-like summit, from which, with a general direction toward the southeast, descends a system of deeply eroded ravines. These gather themselves finally into two main streams, Gold Cañon and Six-Mile Cañon. The upper portion of the range sends out to the southeast lofty spurs which descend, with extremely abrupt slopes, to the levels of Virginia City, Gold Hill, and American Flat. Mount Davidson, the culminating point of this region, projects a spur which, continuing southeast to the Carson Plain, divides the drainage of the district; all the water from its north side flowing into Six-Mile Cañon, that from the south into Gold Cañon. Skirting the base of the first great step of the

mountain descent is a comparatively level region, and at the junction of this steep summit slope with the plateau is the Comstock lode.

About four miles to the east, and, in general, parallel to the summit, rises a lofty ridge, whose most prominent points have been called Mount Kate, Mount Rose, and Mount Emma.

The surface of the district is rendered extremely rough by a labyrinth of cañons, which are deeply cut in all directions. An idea of their depth may be gained by a brief study of the contour lines of the map. For instance, the vertical distance from the central street of Virginia to the summit of Mount Davidson is about 1,700 feet, and from the bottom of Six-Mile Cañon, opposite the Sugar Loaf, to the summit of Mount Emma, is 1,300 feet. The Gold Cañon, just above Silver City, 700 feet. The slope of Cedar Hill, from its summit to the Geiger grade, which may be seen following an approximate grade curve, is 1,100 feet. Nearly all the lesser ravines will average 300 feet in depth.

The following list of altitudes of several important points in the district conveys a general idea of the average elevations, expressed in feet:

| | |
|---|---|
| Mount Davidson | 7,827 |
| Virginia City, C Street | 6,192 |
| Summit Cedar Hill | 7,235 |
| Pass at head of Gold Cañon | 7,527 |
| Gold Hill Divide | 6,366 |
| Quarry Hill, Virginia City | 6,462 |
| Cone east of Gold Hill | 6,240 |
| Pass of American Flat grade | 5,886 |
| Sugar Loaf | 6,164 |
| Mount Kate | 6,187 |
| Mount Rose | 6,448 |
| Mount Emma | 6,546 |
| Signal Peak on ridge north of Sugar Loaf | 6,621 |
| Devil's Gate | 5,105 |
| Carson Plain | 4,700 |
| Washoe Plain | 5,106 |

Looking from Virginia, the ridge, culminating in Mount Emma, nearly closes the eastern view, except where the deep cut of Six-Mile Cañon opens

a gateway to the Carson Desert. The whole configuration of the surface is one massive pile of hills, steeply sloping into deep, narrow ravines.

As the description proceeds, it will be seen that the topography owes its characteristic forms and its rapid changes of slope to the great variety of rocky material. Indeed, there is scarcely a more interesting example, within the limits of the exploration, of the complete subordination of surface form to geological structure.

At the western edge of the map, and a little to the north of its center, is a mass of syenite, bounded upon all sides by a more recent volcanic rock, to which Baron Richthofen has given the name of propylite.

Propylite occupies the broad zone from north to south through the center of the map, broken by chains of outcrops of andesite, which have burst through it on lines approximately parallel to the summit of the range. In the southwest corner is a complicated association of metamorphic rocks, overflowed first by quartz-propylite and, more recently, by outbursts of basalt. At the deepest part of American Cañon, and at the lowest exposure of metamorphic rocks, is a small outcrop of granite, the only occurrence of this rock nearer than the summit of the Pine Nut group. Along the east side of the map, and covering nearly a quarter of its area, is an immense overflow of sanidin-trachyte. It is of this material that the high summits of Mount Kate, Mount Rose, and Mount Emma, and the prominent cone of the Sugar Loaf, are formed. Arranging these rocks according to their relative ages, we have, first and earliest, the metamorphic rocks, uralitic and mica schists and limestone, with an unimportant accompaniment of granite; next the syenite, which, with the first mentioned series, is all we have left of the original Jurassic range. Superimposed upon this slope, outpoured, first, the trachytic greenstone known as propylite, which, over all the upper portions, was a sub-ærial ejection, but, as it approached the lowlands, was finally poured out beneath the level of the great fresh-water lake which formerly skirted the range. The evidence of this is to be found in the tufaceous form of the propylite, which shows all the phenomena of aqueous arrangement and stratification. Leaves of Tertiary plants are found in the tufa at the height of about 700 feet above the present bed of the Carson River. The propylite formation is of considerable orographical importance, for over a

large portion of the Virginia Range it occupies a wider area than any other rock. It is noteworthy, also, as forming one of the walls of the Comstock lode along its most productive portion.

Following the propylite, but after a lapse of time which permitted a considerable erosion, three parallel fissures were broken through the propylite and large volumes of andesite were thrown out. Still later, and near the close of the Tertiary period, a violent eruption of sanidin-trachyte took place, piling up important mountain ridges and burying beneath repeated overflows perhaps one-fifth of the range. Following rapidly upon the trachyte period came outbursts of rhyolite. Lastly, closing the eruptive series, and filling out the entire catalogue of the volcanic family, came floods of basalt, which seemed closely to conform to the fissure lines of the rhyolite and trachyte periods. They are indicated upon the map in the southwest corner.

Here, then, within these narrow limits, are the evidences of a long, complicated geological history. It is rare to find, within such a small area, all the representatives of the volcanic family, and with them the relics of one of the ancient ranges.

The three sections of Plate I are constructed on a horizontal scale of 3,520 feet to one inch, one-half the scale of Atlas-Plate II, and a vertical scale of 2,000 feet to one inch.

Section 1 is through the summit of Mount Davidson and the Sugar Loaf

Section 2 cuts through Gold Hill and crosses the trachyte ridge half-way between Mount Rose and Mount Emma.

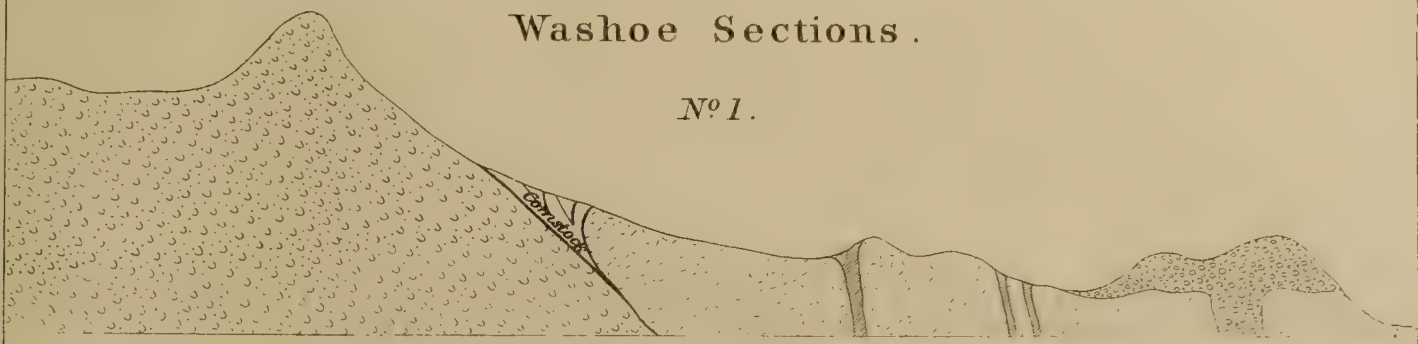
Section 3 is on the southern line of the map. All are on due east and west planes.

The reader, by comparing these with the position of the rocks on Atlas-Plate II, will easily perceive the general geological relations of the district.

To examine this history in sequence, to present the evidences of its correctness, and a somewhat detailed description of the mode of occurrence of the several formations, is the purpose of the present section. They will be examined in the following order: The crystalline schists, the uralitic-metamorphic rocks, and the limestones, calling these three the metamorphic series; next, the granite and the syenite, which constitute the older eruptive series; and lastly, the volcanic series.

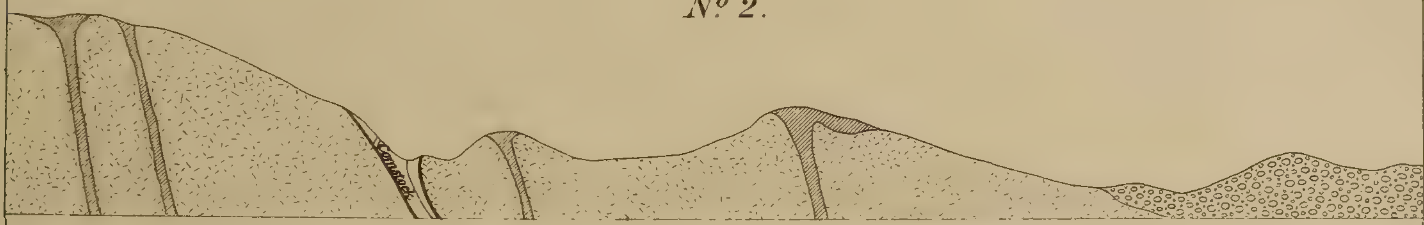
# Washoe Sections.

N° 1.



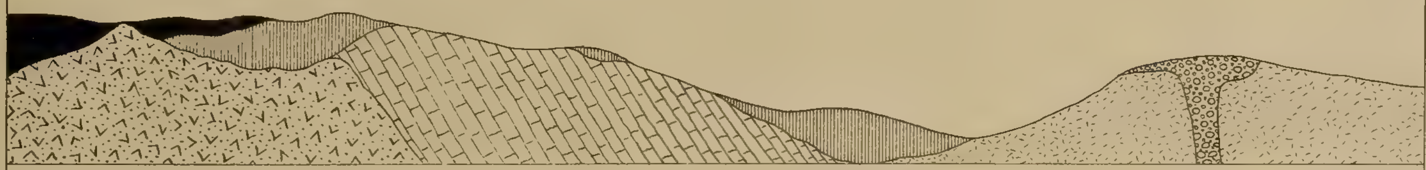

*West to East through M^t Davidson and Sugar Loaf.*

N° 2.




*West to East through Gold Hill.*

N° 3.



*West to East on Southern limit of Map.*

GRANITE. | SYENITE. | TRIASSIC METAMORPHIC. | PROPYLITE. | QUARTZ PROPYLITE. | ANDESITE. | TRACHYTE. | BASALT.

**HORIZONTAL SCALE:** *3520 feet to 1 inch.* **VERTICAL SCALE:** *2000 feet to 1 inch.*

The district, then, is an accumulation of volcanic rocks built upon the eastern slope of an earlier range. We have the evidence of an original chain in the syenites and metamorphic rocks, and we have, clearly superposed in their normal sequence, the propylite, andesite, trachyte, and basalt flows; and, finally, are observable the results of intense aqueous erosion, which has scored the mountain slopes into sharp, deep ravines. It is an epitome of the whole Great Basin, and it is doubtful whether anywhere else over the entire Cordillera system can be found, in the same narrow limits, a representation of every important geological event. The points in this geology which affect the Comstock silver lode are, first, the mass of ancient rocks which slope steeply to the east; secondly, the propylites which overflowed these rocks to a given height; and thirdly, the andesites, which, in the form of an obscure, thin dike, have burst out on the contact plane of syenite and propylite; fourthly, the immense solfataric activity to which the vein unquestionably owes its origin, and whose influence is recorded in the decomposed propylites lying east of the vein. The andesites overlying them are untouched. The general thermal activity was confined to the interval between the out-flow of propylite and that of the later andesite. To this period is assigned the Comstock lode. ✓ The thermal action which began at the dawn of the volcanic period, we behold at present in its last stages. It is probable that long after the great solfatara had ceased altogether, the Comstock remained the theatre of great activity, and that only in most recent times has intense chemical and dynamical action abated.

Granite and Metamorphics.—The granite which occurs in American Cañon is composed of opaque dull-gray orthoclase, combined with an unusual proportion of translucent quartz, and containing a small and variable percentage of green mica in half decomposed hexagonal plates. The feldspar closely resembles that which occurs in the general mass of syenite, and is entirely distinct from the adularia variety which is characteristic of the majority of Jurassic granites in Western America. Resting upon this, and upon the syenite, lies the series of metamorphic rocks which were briefly alluded to in the general description of the range. Leaving out of consideration the carbonaceous shales and slates of Eldorado Cañon, where Professor Whitney found the Triassic fossils, the metamorphic rocks belong

to two distinct groups; a series of thin, imperfectly developed, highly altered limestones and another group of crystalline schists. Richthofen attempts a subdivision of these schists, and makes a classification which does not seem to hold good upon a more extended study. It is preferable here to consider them as one series whose variety is due rather to metamorphism than to original difference. Lowest of these, and lying in direct contact with the granite and syenite, is a series of beds of mica schists, striking in general a little west of north, and dipping at a high angle to the east. The lowermost strata are of a coarse nodular schist, containing dense nuclei of hornblende, a considerable proportion of quartz-granules, magnetic iron, and enough magnesian mica to impart the fissile structure. In ascending the series the mica schists are found to grow finer and finer, the nodules gradually diminishing from the size of a bean until they entirely disappear, the rock at last becoming a fine mica slate. The ridges to the south of American Cañon are composed of these fine-grained schists, and the traces of bedding, and even of fissile structure, are gradually obliterated, resulting finally in a compact black crystalline rock which, in hand specimens, would unquestionably be classed as basalt. A suite of specimens in the possession of the Exploration completely shows this transition from the nodular schist, up to the compact crystalline rock, which has no trace of aqueous origin.

The limestones cannot be assigned definitely, either as regards superposition or relations to the syenitic core. They are very limited, being accidentally excavated from the propylites by erosion. Above the American Flat road, about a mile from Gold Hill, are the only outcrops of the formation. It appears here as a highly crystalline marble, having an almost granitic appearance, and impregnated throughout its whole mass with small crystals of iron pyrites.

The third series of metamorphic products are found dispersed throughout the district: first, as an intermediate zone between the mica schists and hornblende; secondly, in limited outcrops in Crown Point Ravine; thirdly, in obscure masses within the Gold Hill workings of the Comstock; and, fourthly, on the slopes of Cedar Hill. At the latter locality they are mere outcrops, emerging from the general mass of propylite; they are of a light greenish-gray tint, and of a prevailing felsitic character. The fine-grained, compact mass is everywhere studded with pyrites,

and not unfrequently tinted with the chrome-green of decomposed hornblende. Occasional augitic forms, transmuted into hornblende, give it a uralitic character.

From a great accumulation of evidence, gotten in other parts of the Great Basin, it is believed that these metamorphic series are above the Carboniferous, and that the limestone is one of the upper members of the great Triassic series, which is developed on such a grand scale to the eastward. The green felsite of Crown Point Ravine probably underlies the limestone, and is the continuation of the same bed which overlies the granite in American Cañon. All the metamorphic rocks are traversed by a net-work of minute veins hardly thicker than a sheet of paper.

Syenites.—The syenites occupy the summit for the space of about two miles square, just above the city of Virginia. Here is a large, bold outburst of the formation, rising from the level of the town and extending back to the west slope of the range. The summit of Mount Davidson is about the center of the body. It is bounded upon the north by propylite, which forms the northern slope of Ophir Ravine. The Crown Point Ravine marks its southwestern limit. Thin, dike-like ridges project still further to the south, finally losing themselves under the propylite. It is really an insular mass, one of the ancient original summits, which is completely surrounded by the subsequent propylite. In one of the ravines which cut the basalt divide, separating American Flat from Spring Valley, is a small, obscure outcrop of syenite. This, from its remoteness and extremely limited size, merits no attention. The Davidson mass is in plan a rough parallelogram, rising in the center to an elevation of 7,827 feet. It is cut from west to east by two sharply eroded ravines, transversely to its summit line. The overflow of propylite has failed to cover two narrow dikes which still outcrop on the slope of Cedar Hill. These spiny ridges, together with the Spring Valley outcrop, indicate a very wide extent of syenite buried beneath the later eruptive rocks. In general the slopes of the syenite are smooth, although they occasionally weather in sharp, fantastic pinnacles. A prominent example of this castellated structure may be seen at the head of Gold Ravine, where, rising from the general slope of Mount Davidson, are several groups of needles ranging from 30 to 150 feet in height.

The mass is of a prevailing cold-gray color. Mount Butler shows upon its eastern front clouded stains of red, which are probably the traces of solfataric action. There are discernible through the general gray mass occasional lenticular portions of almost jetty black, but they are unimportant features. An attempt to develop parallel planes is observable on the slopes of Mount Davidson, and a general conoidal structure, suggesting its alliance with the granitic family, characterizes the structure of Mount Butler. Weathering has developed prominent lines, which traverse the parallel north and south plains, and seem to be a lithological rather than a structural feature. The syenite is exceedingly dense, of high specific gravity, and so tough as to break with great difficulty under the hammer. The shingle, or débris, which covers almost its whole surface, is formed in sharp, angular fragments, whose great hardness effectually prevents disintegration, so that there is little tendency to decompose, and, in consequence, almost no syenitic soil. The rock is composed of orthoclase, green hornblende, and titanic iron, having, as an occasional accompaniment, oligoclase and epidote. The average rock is a crystalline blending of orthoclase and fibrous, broken particles of green hornblende; the prevailing purplish-gray of the former toning the whole rock. The hornblende crystals are chiefly grouped about small nuclei of titanic iron. The approximate proportions are, orthoclase, 75; hornblende, 24; titanic iron, 1. They were evidently of synchronous origin—the hornblende penetrating the feldspar in certain cases, and in others the reverse. Each prism of the hornblende contains within it more or less crystalline particles of the feldspar, and, with the exception of certain porphyritic portions, the feldspar invariably contains some fibrous particles of hornblende. At rare intervals, brilliant, flat crystals of black hornblende occur, cutting both the orthoclase and green hornblende. Oligoclase traverses the ordinary syenite in veins from the thickness of a line to a foot, usually segregated from the orthoclase rock by an accumulation of microscopic hornblende crystals. Oligoclase also occurs in lenticular bodies, scattered at intervals through the entire mass, within which the hornblende groups itself in radial forms, and in each case penetrates the oligoclase. We have, then, the following paragenetic succession of constituents: Titanic iron; orthoclase and green hornblende; fibrous, radiating, olive-colored hornblende; oligoclase; and,

finally, the epidote, which last occurs but sparingly in fine green veins and in small crystals accompanying the acicular quartz vugs. The orthoclase rarely defines itself in completed forms, but is usually a crystalline mass, very fine-grained, and only in occasional fractures showing its characteristic striæ.

On the south slope of Cedar Hill rises an insular ridge. It is a large outcrop of porphyritic syenite, composed of a paste of mixed orthoclase and hornblende, in which are imbedded well-defined crystals of both; the orthoclase occasionally appearing in twin forms. Near the Cole Tunnel, without any evidence of fissuring, and lifted above the average line of solfataric action, the syenite has a cellular, almost porous, structure, resembling the scoriaceous products of modern volcanoes. Frequent vugs occur, lined with the acicular prisms of quartz and cubical crystals of iron pyrites. The feldspars show a considerable advance in earthy decomposition. The orthoclase is honeycombed and its cavities refilled with yellow pyrites. On the south side of Ophir Ravine there are portions of the syenite which become microcrystalline, a mere paste, of a dull greenish-gray color, resembling dolerite; without the aid of the glass no crystalline particles can be detected. The fracture, instead of the ordinary sharp, transverse break, becomes conchoidal, and the ordinary weathering develops spherical forms. Here, too, the interior of the rock is variegated with veins of iron pyrites, which, although not a constituent part of the stone, are a very important accompaniment. It is difficult to conceive how these minute veins and vugs of sulphide of iron have been introduced into the rock without any signs of fissures which could possibly be connected with the main solfataric opening. That they have some subtle connection is clearly proved by the similar threads of zeolites, minerals entirely wanting in the composition of syenite, and occurring here with every evidence of aqueous origin.

The syenite is one of the ancient summits of the Virginia Range, and its contour has evidently undergone but slight change in the later periods of erosion. This is proven, first, by the entire change of ravines when they emerge from the syenite and cut into propylite; secondly, by the contours of Mount Davidson which are developed in the underground working of the mines, and indicate that the surface slopes continue to an indefinite depth beneath the propylite with almost no alterations. The west wall of the

Comstock lode is, in fact, this downward projection of the syenite slope, and its contours agree very closely with those traced upon the surface. It seems probable that in the Post-Tertiary erosion period this syenite nucleus of the district was very little modified; its already sculptured ravines would have received the modern drainage and poured it out upon the later eruptive rocks at the mouths of its own cañons; so that the fact of the present water-courses continuing alike across the syenite and propylite is no evidence that they were formed at the same time. A brief study of the contour lines of Mount Davidson and of the geological cross-sections of the Comstock lode will show that the slope angle has almost no change beneath the propylite, and the recess which takes place in the Savage and the Gould and Curry will be found to almost exactly coincide with the broad recurve which scoops the whole front of Mount Davidson; so, also, the spur which makes out from the southeast foot of the mountain is carried downward through the Chollar Potosi and is there a barrier to the deposition of ore.

Syenite of a similar character, and bearing the same relation to the ancient series of metamorphic rocks, is found in different localities over the whole basin; its mode of occurrence is always the same. Wherever observed it always accompanies the mountain fractures of the Jurassic period, and is clearly distinct from the syenitic granite, which is also a prominent feature of this period; it seems to form a connecting link, both in age and geological features, between the granitic family and the more modern volcanic group; always later than the granite and always earlier than the propylite, it is more closely connected with the former than the latter, both as regards its lithological habit and in the interior structure.

It shows no tendency here or elsewhere in the Great Basin to pass into the syenitic granite. Ordinarily of a finer texture and more compact structure, it is clearly to be distinguished from that rock—the titanic iron of the one is never found in the other; nor does the quartz, which is a constant accompaniment of the syenitic granite, ever appear in the more basic syenite, yet their outward resemblance is very great, and they are often mistaken one for the other.

The transitions described between the two by Von Cotta are not observed here. Of its connection with the folded rocks, it can only be said, that it pene-

trates them in dikes. With the subsequent volcanic rocks its connection is even less intimate, for a very considerable period elapsed between the cooling of the one and the outpouring of the other.

Propylite.—With the exception of the syenite summit, or Mount Davidson mass, the entire Virginia range, in this region, was formerly covered by an outflow of propylite. Subsequent eruptions have buried and masked it to a considerable extent, but enough still remains to define satisfactorily both its relations to the other rocks and its peculiarities of occurrence.

North and south of the syenite mass, propylite occupies the summit, and descends to the plain on either side. From about the elevation of Virginia City it stretches eastward in bold undulations until overflowed by the great north and south trachyte ridge. Its line of contact with the syenite marks the location of the Comstock lode. Along the entire front of the Davidson ridge, the great silver lode occupies the contact plane between these two rocks. To the north, it continues its course inclosed entirely in the propylite. Southward in like manner from Gold Ravine, as far as we are able to trace the vein, it is walled on both sides by the propylite. In Ophir and Crown Point Ravines the propylite is seen to be superimposed upon the older syenite and to penetrate it in well-defined dikes. In a southeasterly direction this rock continues quite to the Carson plain, with the interruption of occasional dikes of andesite, which cut it in north and south lines and overflow it in limited areas.

The great trachyte to the east gives way again, along the eastern foot-hills, to propylite. A considerable variety of eruptive rocks have broken through and overwhelmed the propylite, and will be separately treated of under their appropriate heads. In general, then, the whole eastern slope, in the region of Virginia, is a vast overflow of propylitic rocks, which has failed to cover the lofty summit of the Davidson syenites. To the north, it buries the whole of the earlier formations, and is in turn built upon by successive outflows of later rock. Its normal composition is oligoclase and green hornblende. Every variety of texture in the arrangement of constituents is observable. The predominant rock is a paste of micro-crystalline oligoclase and green hornblende, in which appear well-defined crystals of the former, giving, together with the clusters of hornblende needles, a porphyritic structure. The oligoclase

defines itself, at times, very well. Its angles are generally quite imperfect, but in the less altered portions of the formation, especially near the summit of the range, the orthoclase is well crystallized. Here it possesses a purely vitreous luster, and is intersected by numerous cracks like the sanidines of the trachyte lavas. The ordinary variety of hornblende is a pale green crystallization, formed of clusters of fibers. Although apparently loosely put together, they are often strangely coherent, and give to the rock its unusual toughness. The prevailing dull green is given to the formation by the hornblende. As occasional, although unimportant, minerals occur black and dark-brown, bladed crystals of hornblende, showing on many of their lateral planes an evident striation. These are very brilliant in contrast with the dull earthy luster of the green hornblende. In general, oligoclase takes precedence in perfecting its crystalline form. The specific gravity of the rock is 2.66. The general texture is rough, like that of the trachyte family. The rock is extremely coherent, so that, like the syenites, it breaks with very great difficulty. An unusual variety of texture, and even mineralogical constitution, is embraced within the family which Baron Richthofen has grouped under the name of propylite. In the ordinary nomenclature this Washoe variety would be classed as an oligoclase-hornblende-trachyte. It has an important connection with silver veins, as will be seen by the geographical distribution indicated by Richthofen.

The prominent silver districts of the Carpathian, and some of those of Mexico occur, either inclosed, or associated with it. In this country we have the Comstock Lode, several of the veins in the Aurora District, some of those in Silver Mountain, and the Moss Lode of Arizona. It is interesting to observe this wide range of association, although it seems improbable that the rock itself is a factor in the production of silver deposits. An analysis of the Washoe propylite shows no trace of silver.

Its occurrence in the Virginia region is characterized by great varieties of surface form; varieties which depend partly upon differences of origin, and are largely due to the solfataric action which has so generally decomposed it and facilitated aqueous erosion. Back of Middle Hill, just north of Virginia, on an intermediate spur between it and the Ophir Hill, are bold castellated outcrops of hornblendic propylite, very dense, tough, and of ragged, roundish

fracture. On Middle Hill itself, rising through masses of silicious and feldspathic metamorphic rocks, are high dikes of porphyritic propylite. On the hills west of the Geiger grade there are also, lifted above the general level, hard slabs from twenty to seventy feet high, which are evidently the crests of dikes, whose superior hardness has prevented their weathering with the surrounding rock. Half way up Crown Point Ravine are further instances of the turreted form.

There is evidence that over the country included in the map there have been three successive outflows. From the series of fissures, which traversed the whole surface of the older range, appeared at first a form of porphyritic rock, unvarying in composition, but having every variety of arrangement of the crystalline particles composing it. This is the normal propylite, from a typical specimen of which the analysis, given in the third section of this chapter, was made. Succeeding this was ejected a vast amount of propylitic breccia, which slopes in gently inclined beds toward the Carson Plains. Finally, traversing these two, were a great number of fissures, which were filled with a highly crystalline form of the rock. The earlier porphyritic form is that which rests against the slope of Davidson, and forms the east wall of the Comstock lode. The second, or breccia variety, is found chiefly to the north and south of the lode. A purple occurrence of this breccia caps the Geiger Summit, and, south of the lode, the hills adjoining Mount Butler are formed of a finely fractured mass. At several points, usually near the contact with the syenite, there is observable a fine lamination of compact, close-grained rock, which resembles very closely some of the metamorphic (uralitic) rocks, and still more closely the metamorphic diorites of the California gold belt.

Above the level of the Comstock the whole of the propylite is unaltered, with the unimportant exception of the hill next south of Mount Butler, but below that elevation, quite to the Carson Plain, the whole rock is decomposed to a greater or less degree. Innumerable fissures have traversed it in a north and south direction, and each appears to have been the theater of an intense hot-spring action. The results of this solfatarism are evident in the generally decomposed and earthy condition of the formation. The series of flats are wholly formed of this altered

rock, and it is rare at any point east of the Comstock Lode to find more than an accidental relic of unaltered propylite. The chief product of the thermal action is a soft, yellow, ochreous rock, which easily weathers, and develops near its surface parallel and concentric planes of decomposition. An exceedingly beautiful variety of agate-like banded propylites are found on the divide. The white steam-cracks thread the formation in all directions, and seem to be the centers of decomposition. Not all of the solfataras appear to have been oxydizers. At rare intervals, over the whole outcrop, may be found white, decomposed, chalky masses which may be easily cut with a knife; but in all these extreme products there is still discernible the crystals of feldspar which originally gave it its porphyritic form. Olive and gray and purple are colors which occur frequently, the earthy crystals of orthoclase being dispersed in white specks throughout the mass. The ochreous product appears to be chiefly a mixture of silica, clay, and sesquioxide of iron. The white portions are either entirely free from iron, or else contain it in the protoxydized form. West of the Comstock lode and near the Belcher Mine are two parallel lines of solfatarism, which in both cases have produced the white product, the upper one closely resembling certain of the white trachytic tufas. It is difficult to distinguish between hand specimens of both.

As the range descends toward the Carson Plain, especially in the region of the Daney Mine, the propylite is of subaqueous origin and consists chiefly of an earthy tufa deposit clearly stratified, and containing impressions of leaves and rolled masses of the original propylite. Covering this tufa deposit are beds of yellow clays, which are evidently washed down from the solfatara region. The area of the most intense hot-spring action begins about five hundred feet east of the Comstock, and continues for two miles still further to the east.

In the southwest corner of the map appear irregular masses, colored as quartz-propylite. These rocks overflow the propylite, the metamorphic rocks of American Cañon with their accompanying granite, and are in turn capped by basalt. Little can be learned of their origin except that they succeed the propylite, as is evidenced by their cutting it in dikes above the American Flat road. They are of very great variety of texture and constitution, ranging all the way from a propylite, containing here and there an occasional grain of

quartz, up to a comparatively light trachytoid porphyry, thickly studded with granules of vitreous quartz. Upon the one side it seems to be clearly allied with the propylite, so that it may be classed without difficulty as a quartz-propylite, but at the other extreme it becomes so acidic as to approximate closely to the rhyolites. Above American Flat the prevailing form is a compact, slightly porphyritic, green mass, having in general a felsitic appearance, containing a small proportion of quartz granules. In the region of Silver City, where it surrounds the overflows of metamorphic rocks, as also at the Justice vein, it seems to have made considerable progress toward the rhyolitic form; and still further to the southward, upon the flanks of basalt hills, its feldspar has become glassy, and is associated with a large percentage of free quartz. The resemblance to the rhyolites is heightened by a film of red silicate of iron, which surrounds the quartz and gives them the garnet tints. The quartz-propylites of the Silver City ridge are generally of a deep, brownish-purple color, becoming lighter to the southward, until, near their contact with the basalt, they have attained the light chocolate and pinkish tints of the rhyolite family. Mica, which was a prominent mineral north of the American Flat road, has almost entirely disappeared, and the paste has changed from a felsitic to a trachytic texture. The two outcrops are not connected, and it is still possible that the westernmost one is a true rhyolite, but from the gradual transition from the other extreme, it seems probable that they are only various forms of the same rock. As will be hereafter seen the balance of probabilities indicate that it is all propylite, for the solfataric fissures penetrate and alter it as they probably could not have done were it so recent a rock as rhyolite. West of the American Flat road the quartz-porphyries appear in bold dikes, or rather longitudinal masses, for their great size entitles them to a more important term than dike. It is interesting to observe that the white solfataric product of the quartz-porphyry is identical with that of the feldspathic propylite, with the exception of the granules of quartz, which the chemical action has failed to touch. In the unaltered rock may be seen crystals of oligoclase, and accumulations of hornblende, exactly resembling the original propylite. Interrupting these a second quartz-porphyry, has flowed out which, although still closely resembling the propylite family, begins to tend toward

the rhyolites. A fissile, parallel structure further indicates the increase of trachytic tendency.

ANDESITE.—The first appearance of a later rock than the propylite is found in the andesite dike lying along the contact plane of Mount Davidson. The earliest andesite probably inaugurated the solfataras. Near the close of their activity, or perhaps subsequently, there were formed three zones of fissures which traversed the earlier and volcanic formations alike. Through them there penetrated to the surface, and outpoured to a considerable extent thin table-like overflows of andesitic rock. The first, or summit zone, consists of a group of conchoidal fissures, following approximately the summit line, and cutting through the syenites of Mount Davidson, as well as the propylites both north and south of it. On the heights above the Ophir grade considerable fields of andesites cover the summit, and pour downward over the propylite to the north of the road.

Ascending Crown Point ravine two of these dikes are passed, with an intervening distance of a thousand feet of propylite. Their outcrops rise boldly from the surface on either flank of the ravine, and from the average appearance indicate a thickness of a hundred feet. Directly west of the summit of Mount Butler, and at a corresponding point on the Davidson ridge, the same system of andesite dikes are passed. They have overflowed here a wide area, and the débris covers the western slope to a distance of a thousand feet downward. Continuing northward, with a break from Middle Hill to the crest of Ophir Hill, upon the level plateau-like summit, has been ejected a considerable table.

The second zone, parallel to the first, traverses the American Flat and the plateau in front of Virginia, its outcrops disappearing to the northward under the later outpourings of the sanidin-trachyte. Rather more continuous than the first zone, the outcrops are, however, less expanded, and a subsequent erosion, which has largely worn them away, reveals an extraordinary thinness of flow. Approaching Virginia from the south the first of these andesite fields is found upon a rounded knoll south of Gold Hill, where for an area of ten or fifteen acres the entire surface is of andesite. Thin streams have poured from a narrow fissure downward toward Gold Cañon, partly covering what is known as the Graveyard spur. Continuing northward, the sharp conical

point due east from Gold Hill is also of andesite. It is wholly surrounded and limited by propylite, and leaves a doubt as to whether it is a normal part of the fissure system, or simply a relic of one of the overflowed fields which has been spared in the general erosion. Accumulations of clay propylite soil cover the surface for half a mile northward and mask all rock in situ. Near the railroad tunnel, directly to the north of the Dayton toll road, appears a third mass of andesite, of a long oval form, tapering to the northward in a thin spine-like ridge. Earthy deposits again cover the surface from this point until about opposite Taylor street, where, among the first occurrences of solid rock, the andesite again makes its appearance, this time in a mere thread which traverses the bottom of the Slaughter-House Cañon.

Where the road to the Odd Fellows' burying ground diverges from C street, the same dike reappears. This whole zone bends slightly in conformity to the foot of Mount Davidson, and seems to be a proof that the underlying syenites have in great measure determined the direction of subsequent fissures to the eastward.

Zone number three, and by far the most important of all, lies concentric with this last, and about two miles to the eastward. An almost continuous overflow of andesite covers the country from near the Devil's Gate, in Gold Cañon, across the Divide spur, continuing northward across Six-Mile Cañon, covering a large part of the Silver Terrace Spur, and reappearing on the Catholic burying ground. The indication of a third, but much more limited group, is found in a train of small outcrops which lie directly along the edge of the trachyte, and without doubt underlie it.

Under its proper head, in the volume on Systematic Geology, will be discussed two important questions concerning the andesite formation. First, its origin and relation to other allied rocks; and second, its own chemical and mineralogical constitution, concerning which authorities differ so widely and on the basis of so few data that the whole question is at present in a form unprofitable to discuss. In general terms, however, it may be said here that the balance of probability points to a close alliance between this rock and propylite, and it will not be at all surprising if it should finally prove to be chemically identical and, in reality, only a different form, bearing the same relation to the typical propylite as the hyaline-pearlites and obsidians do to the

trachyte family. Its mode of geological occurrence enables the observer to detect it without fail on the ground. Its appearance, and especially the tendency to break in parallel planes, distinguish it from all other kindred rocks. The prevailing color is a dark greenish-gray, inclining to purple and black. The luster, although varying greatly in degree, is almost uniformly resinous. It is formed chiefly of a vitreous, compact, feldspathic paste, but is not unfrequently distinctly porphyritic, and finally, by a series of gradual approximations, shades in to the more crystalline propylite. Oligoclase, hornblende, occasional but rare occurrences of magnetic iron, are the chief constituents, but the peculiar texture and parallel fracture are given to it by a prevailing brilliant, glassy feldspar, which being transparent, does not alter the general color. The nature of this feldspar is somewhat obscure, although it is most probably the so-called andesine.

In certain instances, as is the case in most of the Gold Hill andesite occurrences, the paste becomes exceedingly vitreous, approximating closely to obsidian. Comparing a large number of specimens, the conclusion is almost inevitable that its wide variety of texture is wholly due to the condition of the feldspar. It is proposed to call this peculiar feldspar andesine, without regard to its chemical origin. With some hesitation, the black dike which occurs in various parts of the Comstock lode is referred to this rock. Highly altered, and in some places reduced to a mere clay, there are some evidences, to be hereafter discussed, which induce the belief that it is andesite. If so, it belongs to a fourth zone intermediate between numbers one and two.

One very marked fact, and an important one in connection with the geology of the Comstock, is, that while all of the propylites east of the foot of Mount Davidson are in a highly altered condition, the andesites which directly overlie them show not the slightest trace of solfataric action. From the mineralogical characteristics of andesite it would seem impossible that this could have been the case if solfataric action had continued after its outflow. Every fact corroborates the idea that the age of general solfatarism had closed before the later andesitic ejection; and this is important as limiting the period of formation of the Comstock lode to a point anterior to the sanidin-trachytes in whose eruption Richthofen has found a cause of the Comstock solfatara. It is

further evident, from the position of the andesite cappings, that nearly all the surface erosion, which has determined the configuration of the whole district, was subsequent to the andesite period. It occupied then an interval of geological calm between the intense solfatarism and the turbulent conditions of trachyte eruptions and erosion forces which followed. Nowhere else in Nevada does this rock come into such close connection with a silver district. Its usual position in the volcanic group is normally continued here. Throughout all of our observations on the volcanic rocks of the Great Basin it is invariably subsequent to the propylites and anterior to the trachytes. With the single exception of its lithological constitution, this rock follows closely the geological habits of basalt, and until a comparatively recent period has been classed in that family.

Trachyte.—About on the level of Virginia City, and not far to the east of it, there outcrops a line of trachytes. The most northerly of these is on Graveyard spur, at what is known as the Quarry. Capping an abrupt hill is a comparatively thin sheet of sanidin-trachyte. Throughout this outcrop is a well-marked tendency to jointing planes which have a north and south direction, and a dip of about 70° to the south of east. These planes are again jointed in rude hexagonal columns. The greater mass of the trachyte is formed of these inclined prisms, varying in size from a foot to four feet across. Unlike most volcanic columns, they are frequently curved, and in certain cases broken and pushed to one side. The rock weathers of a reddish-gray, with an exceedingly rough surface, upon which protrude prominent crystals of sanidin and hornblende. The base of the rock is a fine, gray crystalline paste, chiefly formed of sanidin and black hornblende, throughout the mass of which crystals of both these minerals are dispersed, associated with spangles of black mica. Oligoclase is not unfrequently present.

The second outcrop occupies a bench just above the Geiger grade, near the Sierra Nevada works. It is quite unlike the former in lithological characteristics, being of a heavy, dull grayish-brown base, containing but few sanidin crystals, occasional, but rare, augites, but neither hornblende nor mica. The mass is an unusually smooth, compact material, of a very dark color and basic appearance. The outcrop is reddened and crumb-

ling, rendering it very difficult to get a specimen Like the Graveyard spur outcrop, it is wholly surrounded by propylite, and from its thinness seems to be rather the fragment of an old overflow than the outpouring of a local dike.

About a half mile east of the Virginia divide is a third but exceedingly small locality of the trachyte. It consists of a mere accumulation of blocks, dispersed about the surface, and indicates probably the limit of the trachyte flow in that direction. It is a sanidin-mica-trachyte. The study of this third out-crop reveals no traces of subterranean connection; it is difficult to conceive of its having burst out through a local chimney, and it is probably a part of a sheeted overflow.

Two miles to the east of this zone occurs the main ejection of trachytic rock. It occupies a broad zone from the Washoe foot-hills to Pyramid Lake, a distance of forty miles. In a nearly meridional direction it is poured out along the heights of the range, and nearly all of the prominent eroded summits and elevated table lands are formed of it. This formation enters the map at the northeast corner and occupies a broad belt quite across it.

A series of bold hills continue from the Truckee River, almost without a depression, until they reach the pass north of the Gould and Curry mill. Here they descend steeply about 800 feet; ascending to the south of the pass to an almost equal height. The pass itself is wholly of propylite, except a narrow dike of trachyte less than 100 feet wide; through this small aperture the whole mass of the formation has come. Continuing southward, the area of the trachyte widens rapidly until it has overflowed the width of two miles. Across this has been eroded the Six-Mile Cañon, opening up the internal structure of the mass to a great depth. A prominent conical hill seen from Virginia City, and known as the Sugar Loaf, is of this formation, as are also the series of hills which continue thence southward to the Dayton road. Whenever it is eroded to any great depth there may be seen traces of an earlier flow of the oligoclase-hornblende variety of the trachyte. This is especially observable in the most northern part of the map, and again at the base of Mount Rose, where the oligoclase-hornblende trachyte occurs, having a fissile, slaty structure given to it by the parallel arrangement of both oligoclase and hornblende. It is of a steel-gray color, with dull brown parallel planes. There

is a considerable amount of sanidin in its composition, but far less than of oligoclase. Fragments of this earlier trachyte are found embedded in the breccia which immediately succeeded it. These breccias form the majority of the whole outflow. They are of an extremely rough, open texture, frequently scoriaceous, like volcanic products, and of unlimited variety of texture and form. They contain angular blocks of both sanidin and oligoclase-trachytes, varying in size from a mere pebble to blocks twenty feet in diameter. These breccias may be seen in the neighborhood of the Gould and Curry mill, and they form the greater part of the abrupt eastern slope from the pass between Mount Rose and Mount Emma. They weather in large cavernous forms, and the heavy included rock-masses which are constantly liberated by the crumbling paste fall to the base of the eastern slope.

Capping the breccias is a broad, thick overflow of normal sanidin-trachyte, varying in thickness from 100 to 1000 feet. It is of a dull pink color, weathering deep salmon and almost brick-red; it is composed chiefly of sanidin and brown magnesian mica. The crystals of the former average about the size of a pea; they are not of the most vitreous form of the sanidin but rather unusually opaque, are fissured in every direction, and frequently the disjointed halves of the same crystal appear embedded in the paste, side by side.

North of the Six-Mile Cañon road, and below the Gould and Curry mill. there is a very fine exposure of the hornblende variety. It is a lilac-colored paste, surrounding well-defined needles of hornblende, crystals of oligoclase of minute size, and occasional bits of sanidin. This is the most compact and dense of all the family. The Sugar Loaf is composed of a similar base, in which, however, mica replaces the hornblende, its magnesian contents imparting an olive-brown hue to the whole rock. Accidental minerals in this questionable variety are carbonate of lime, rare specimens of glassy quartz, and a zeolitic mineral, which appears to be natrolite.

On the south slope of the Sugar Loaf were found several considerable masses of granite, rounded boulders of which were embedded in trachyte. This is a frequent occurrence in other parts of the Great Basin, although we never find them in either the propylite or basaltic family.

Near the Gould and Curry mill is a quarry from which the foundations

of that establishment were obtained. It is of the sanidin variety, partly a heavy, dense rock, from which the foundations themselves were made, partly a pinkish breccia, very loose in texture, and partly of a grayish, shaly sandstone mass, which is unlike any of the trachyte forms observed in the Great Basin. This is a singular segregation of fine, sandy material which, shading into the other rock, has lost every trace of crystalline structure, and, even under the microscope, appears to be an aggregation of rounded particles, but, as it approaches the main trachyte, gradually becomes more and more crystalline, and passes imperceptibly into the ordinary variety without any apparent junction line. Certain specimens cannot be separated from metamorphic sandstones. Toward the middle, the mass has an open, shaly structure, and constantly slacks under the influence of the atmosphere, like the shales of the Cretaceous period.

Traversing the whole trachyte formation are a series of parallel north and south jointing planes, which, like all the others of the region, dip at a high angle to the east.

The trachytes are easily distinguished from the other rocks of the country by their porous, lava-like texture and the loose porphyritic mode of occurrence. Their limits are always easily defined upon the propylite, which they have overflowed. It is evident that the greater part of the erosion has taken place since the trachyte period, for they share with all the earlier rocks the abrupt sulcated surface.

Basalt.—In the southwest corner of the map there are five patches of black, which represent all that is left of a great sheet of basalt, which, at the close of the volcanic period, poured out over the metamorphic rocks and quartz-propylites. From their mode of occurrence and characteristic jointing, they may be easily distinguished from the black metamorphic rocks of the same region; the latter are traversed by innumerable thin seams of carbonate of lime; the former are impregnated with considerable quantities of olivine. Traces of parallel structure are discernible in the metamorphics, while the basalts are clearly parts of a single flow.

This basaltic table is a feeble representation of a vast ejection which brought to a close the era of volcanic activity.

## SECTION II.

### STRUCTURE OF THE COMSTOCK LODE IN DETAIL.

The Comstock lode lies at the base of the Mount Davidson group and occupies, during the middle of its course, a line of contact between the syenite mass and the propylites which have overflowed it. North of Ophir ravine it is walled upon both sides by propylite; south of the Gold Hill Divide, at a point somewhere in the Exchequer claim, it also leaves the syenite and is carried southward chiefly in propylite, but touching indistinctly the older metamorphic rocks upon its west side. Its course is about north 25° east, or a little east of the magnetic meridian. In Seven-Mile Cañon, near the base of Cedar Hill, is the most northern known portion of the lode. From that point it continues south in a nearly direct line, underneath Virginia City, across the divide, past Gold Hill to American Flat, where the wide-depressed area has produced conditions unfavorable to further development. Upon this entire length are located a series of mining claims occupying the lode for 22,000 feet.

In point of geological time, the system of fissures which constitutes the Comstock lode are subsequent to the propylite outflow, and belong, in all probability, to the dynamical disturbance connected with the eruptions of andesite. It is considered certain that the whole series of volcanic outbursts are since the Miocene epoch, and we may safely call the Comstock a Tertiary lode. (For evidence of the Post-Miocene age of the volcanic family the reader is referred to Baron Richthofen's memoir on volcanic rocks, and to the chapter on the Tertiary period in the first volume of this series.) It is by no means a single crack which has been subsequently filled with mineral material, but forms a connected group of fissures whose structural outlines are quite simple, but whose details produce a complexity almost unknown in metal veins.

Extensive explorations, reaching to a depth of 1,200 feet, have facilitated to a wonderful degree the study of this immense lode; and although certain minor conditions are even yet obscure, there are data for intelligent compre-

hension of all the important facts. For a distance of 1,700 feet the galleries and tunnels, run for the purpose of exploring the silver deposits, have opened up nearly all portions of the vein, and we are able, with almost absolute certainty, to map out the general structure of its interior.

For 4,800 feet syenite forms the west wall. It preserves great uniformity in its dip, rarely exceeding 47° to the east, and never rising to less than 40°. The west wall plane is not a smooth surface, but advances to the east in broad curved projections, to which the name of capes has been given. These gentle swellings are characteristic of the whole syenite surface. They point downward, uniform in dip, with the recurved portions maintaining an average angle of 46° to the east. Southward, and north of the syenite, where propylite forms the west wall, the same curved, buttress-like ribs lie up and down its slope. At a distance varying from 100 to 800 feet further east is the other wall. To the east of this lies the propylite country-rock, which, by some strange accident, is comparatively unaltered near the vein, but at a very short distance to the east becomes decomposed under the influence of the solfataras.

The east wall is still somewhat indefinite; swelling out often toward the east in bold curves, and again approaching the west country, in one or two places it comes into actual contact with the latter. From the surface it descends until it reaches the inclined face of the west wall, at a depth which is generally from 600 to 1,200 feet, although at two places the point of contact is indefinitely deeper. This depth is varied, first, by the irregularities of the surface, and, secondly, by its curves toward the east country or the west wall. It is obvious that the farther to the east it deflects the deeper will be the point of contact. A frequent feature of the east wall is its convexity toward the west. It is one of the largest examples of conchoidal fracture that can be observed.

These two walls, inclining together, form a V-like section. This wedge, produced north and south, results in a long vein mass 20,000 feet in length, varying on the surface from a width of 200 to 800 feet, with the western wall descending at 45° to the east, and a steep east wall intersecting it, at a varying depth of 800 to 1,200 feet.

So powerful has been the influence of the rigid mass of Mount Davidson upon this lode, that, even to the north and south, where it continues wholly in

propylite, the system of fissures induced by the syenite is maintained. After the cooling of the propylite overflow, a thin dike of andesite penetrated the contact plane between the syenite and the propylite, and was undoubtedly the first step in the formation of the lode. Contemporaneously with this andesitic fissure, or with those of the main andesitic outflow, the eastern fissure was formed. To the western is given the name of contact fissure; to the eastern, since it contains nearly all the silver deposits, is applied the term of ore channel. The submerged base of Davidson not only affected the larger outlines of the lode, but has had a tendency to throw the channel further to the east over each of the fluted projections of its surface.

The eastern fissure never penetrates the syenite, but dies out to a mere clay seam upon its unbroken front. Throughout the greater part of the lode there is no appearance of a vein below this junction; but at the Hale and Norcross, and in the Gold Hill group, the contact does not occur, the east wall curving into parallelism with the west. The great ore channel, then, is simply a gash from the surface down into the inclined fissure which lies upon the face of the west wall. The vast deposits of silver which have given to these mines their world-wide celebrity, have been almost wholly mined from this gash, or its connected openings. While the vein, as a whole, can only be regarded as a true fissure, since its deep connections are evident from its chemical and dynamical conditions, yet that particular fissure which has mainly carried the silver is certainly limited in depth by the west wall. The unimportant channels of ore which have traversed the propylite horses, lying between the two fissures, are so evidently connected with the main ore channel, and confine themselves so closely to its neighborhood, that they may be considered as its accompaniments and spurs.

The wedge-like mass of propylite occupying the middle of the lode is considered to be a great horse. It is penetrated with a network of innumerable seams of quartz and clay, and lines which have evidently been the channels of solfataric action. It is generally in a decomposed and spongy condition, frequently having lost its porphyritic texture. This horse is generally subdivided by longitudinal fissures, commonly filled with clay, and terminating downward, near the regions of the walls, in mere plates of pasty material. It is also divided by curved, conchoidal fractures, with their convexity to the west.

Throughout the central portion of the lode these conchoidal fractures, breaking joints with each other, are of frequent occurrence.

Beside the minor changes of the east wall, there are certain general curves to the east, which are connected at the extremities with the west wall, forming a series of separate solfataric vents. The Gold Hill group of mines occupies one of these chimneys; the Bullion and a part of the Chollar Potosi, a second; the Virginia group, a third; the Consolidated and Ophir, a fourth. Of those mines lying north of the Ophir, our information is so meager that we are unable to indicate further chimneys. While there is no reason to doubt that the whole vein was formed by one general solfatara, yet, from the difference of mineralization, both in a quantitative and a qualitative sense, it seems certain that, toward the close of the action, each of these chimneys was a separate outlet.

Only about 12,000 feet will be analytically described; and, for the convenience of study, this central and productive portion is divided into three sections: the Gold Hill group, the Virginia group, and the Ophir group. This is a thoroughly natural division, answering not only to the solfataric chambers but to the bonanzas or ore bodies as they have been found. In general, then, the lode has a longitudinal expansion of 22,000 feet. It is a wedge of material included between an inclined fissure on the west side and a steeper gash communicating with it on the east. The gash, curving east or west in accordance as the west wall recedes or advances in capes, contains all, or nearly all, of the silver bonanzas. The inclined fissure, though bearing here and there small bunches of silver, is comparatively valueless. Both these fissures are more or less filled with continuous veins of quartz, which are lined on both sides with sheets of clay. Clay also fills all the conchoidal fissures of the propylite horse, and percolates into every water-channel within the lode.

Evidence of long-continued solfataric action is present, not only in the accumulations of quartz and clay, but in the peculiar decomposition of the feldspathic material of the horses. Along the west wall, and separating the vein from the syenite, occur at intervals the metamorphosed and decomposed relics of the dike of andesite which was the starting point of the Comstock lode. Finally, grouped according to interesting rules in the sheets of quartz occupying the gash vein, are the bonanzas or silver ore bodies. Currents of heated waters still penetrate the lode from below, and are unquestionably the

lingering traces of solfataric action. Chemical decomposition is yet active here. The vast masses of propylite horses and of clay are to-day quite plastic and working with immense dynamic power. Nearly the whole interior of the lode is in a condition of gentle chemical activity.

Atlas-Plates 3, 4, and 5, are horizontal maps of the underground workings on a scale of 100 feet to the inch. The shaft-mouths are indicated by small parallelograms; the separate compartments are crossed, except the pump-shaft, which is a simple square in black, drawn to the scale of the shaft-section; winzes and inclines, which connect subterranean levels, are in plain black; tunnel-dumps are indicated by half-circles of hachures. Each drift is marked by a separate color, which continues through all three sheets, at an approximately corresponding level. The drifts are numbered, first, according to their depth from their own shaft-mouths; secondly, in brackets with a separate number indicating the depth below a general datum-point situated upon the Gould and Curry outcrop, back of Virginia City. Atlas-Plates 6 and 7, and Fig. I, Atlas-Plate 12, are longitudinal elevations, on a scale of 200 feet to the inch, on which the mine-workings and ore-bodies are delineated as if the vein-materials were transparent. Atlas-Plates 8, 9, and 10 are vertical cross-sections, also at 200 feet to the inch, looking north, and cut from east to west at all important parts of the lode, and colored so as to show its geology. Nos. 11 and 12 are horizontal sections on illustrative levels, also colored geologically.

The Gold Hill Group.—Atlas-Plate 3 embraces 4,300 feet of the southern end of the lode, from the furthest workings of the Uncle Sam to the north Alpha line. It will be seen that this map lacks a few important features, such as the drifts in the mines of Gold Hill proper, which were scarcely ever surveyed at all, and of which, when measured, the records were not preserved.

Considerable exploration-work has been done in the Alpha, but, like the adjoining group of claims, it has no full map. Fortunately, the geological features are quite well understood, so that all questions affecting the general structure of the lode are not obscured by ignorance of the workings.

From the south end of the Uncle Sam the mass of the lode, following

the front of a great mountain spur, trends north 28° east, magnetic, until it reaches the north part of the Yellow Jacket claim, where it makes a curve amounting to an angle of 30°, trending north, magnetic, for about 500 feet; then sweeping west in a sharp recurve around Gold Cañon, projects northward into the Alpha and Bullion. There are indicated on the map a number of points where the east clay wall has been intersected, and whenever the same level develops it at several places its probable course is dotted. Where this is done a glance is sufficient to understand the direction of the vein.

In general plan, this section differs considerably from the portion north of it.

From a line which traces the surface in the curves above noted descend two distinct fissures, each containing an ore-bearing quartz vein, and each partaking of the geological features of the east gash or ore-channel of the northern part of the lode. These two veins diverge at about 50°. The east fissure, varying in dip from vertical to 45° east, continues indefinitely downward, showing, in the present lowest mine-levels, a heavy quartz body with no signs of immediate change; while the west vein dips west at 45° to 48°, descending to a depth varying from 300 to 500 feet, where it is cut off by a nearly horizontal seam of clay and corresponding wall of rock. After leaving the vein, this sheet of clay curves eastward and down through propylite until it nearly joins the selvage of clay which lines the surface of the east body. The position and relation of these two veins are shown in the sections of Crown Point and Yellow Jacket, Atlas-Plate 8. The section through Empire shaft on this Plate marks the greatest eastward dip of the east body; that through the Crown Point shaft indicates the same body 1,600 feet further south, where it has assumed a nearly vertical standing.

Included between the two quartz veins, and bounded in depth by the cut-off clay-wall, is a continuous horse of propylite, which is divided by fissures, filled with plastic clay, whose conchoidal forms terminate downward upon the flat clay-wall or connect with the east vein, separating the whole interior of the lode into a number of water-tight compartments.

Deposits of silver occur in the quartz, distributing themselves capriciously in segregated bonanzas, separated from each other by intervals of entirely barren gangue, or of ore so poor as to be unworkable.

The two quartz veins do not extend southward beyond the middle of the Belcher ground. Whether they were originally one vein, of which the west body is a faulted top, or whether they were distinct fissures, is, perhaps, an open question; but be that as it may, south of the Belcher shaft the conditions are greatly changed. There is but one vein of quartz. It dips west from the surface at a sharp angle, usually 50°, and in depth bends to the vertical, and finally inclines to the east. This sheet of quartz extends from the Uncle Sam to the Belcher, swelling and pinching quite irregularly, and containing, through a zone from 200 to 400 feet below the surface, scattered bunches of ore. In the Overman this silver-bearing area is 500 feet from north to south, the most valuable development being from the 206-foot to the 406-foot levels, where nine small stopes have been made in a vein varying from six to ten feet wide.

The position and limited extent of these argentiferous spots is shown on the longitudinal elevation; Atlas-Plate 6. The whole mass of quartz between and around them is also charged with silver minerals, but not richly enough to pay for working. It would be quite proper to consider them all as parts of one low-grade ore-body, whose true limits cannot be definitely assigned, since the only clues to the bonanza-outlines are the measurements of actually stoped ground.

In the region of the Belcher bonanza there is nothing which at all corresponds with the east quartz body of the Crown Point. The following is the arrangement in the middle Belcher ground. The east selvage rests directly on country propylite, with an inclination west of 45°; it averages three feet thick of tough, dark gray clay, and contains numbers of small, rolled quartz and limestone pebbles, from the size of a pea up to that of a hen's egg; those of quartz remaining firm, the limestone being always more or less decomposed and powdery. Lying upon this, to the west, is a zone 20 feet in thickness, of mixed fragments of quartz and propylite, reddened with iron oxide from the decomposition of small particles of pyrites, which are in all the vein materials. A thin seam of clay and sand, nowhere more than two inches thick, separates this from a second zone of quartz 30 feet thick, which is quite free from any mixture of propylite fragments, but is itself shattered into irregular blocks, the interstices being filled with fine quartz and infiltrated clays. Three inches

of a black, drusy quartz part it on the west from another zone of six feet of ore-bearing quartz; this is also broken into blocks of a foot or less in diameter. Next is 18 inches of black quartz fragments, and rounded, water-worn pebbles; then four feet of white, blocky quartz, separated on the west by a seam of dark greenish-gray clay from what is known as the Hawk-eye horse—a mass of white quartzose propylite extending down to an indefinite distance, with a lateral thickness of at least 300 feet. In general, the section is, first, country-rock and clay parting; then 81 feet of quartz, arranged in zones of different quality; then the white quartz-propylite, succeeded on the west by indistinct propylitic country-rock, into which the 420-foot level of the Belcher has run over 500 feet, but developed nothing important.

In the Crown Point Mine, next adjoining the Belcher on the north, is a totally different structure: see section on Atlas-Plate 8. Here are two distinct bodies. The west vein, as it is called, dips at about 48° to the west, extending down to a vertical depth of 400 feet. Opposite the Crown Point shaft, where it is cut successively by the 160, 230, 300, and 400-foot levels, it is a mere seam at the surface, steadily increasing downward, and reaching a breadth of 20 feet on the 160-foot level, and of 50 feet on the 400-foot level. The quartz composing it is broken and blocky near the surface, and in depth becomes more and more fractured and crushed to a sugary condition. It has a prevailing red tint, from surface infiltrations. Both the selvages are sheets of pure, homogeneous clay, without pebbles, from a foot to three feet in thickness. On the 400-foot level this vein is cut off by a smooth wall of rock, covered with a facing of clay, and lying nearly horizontally, but with a slight inclination to the east. On the section through Crown Point and Yellow Jacket shafts, of this Plate, this body and horizontal cut-off are shown. In the west vein, ore began west of the Crown Point shaft, 75 feet below the surface, and filled the whole vein down to the 400-foot level, with a longitudinal extent of almost 500 feet, running through the Kentuck mine into the Yellow Jacket, for a distance of 200 feet. Its cap-like figure is shown on Atlas-Plate 6, as Crown Point west bonanza. At a distance of 100 feet to the east of the shaft, see section on Atlas-Plate 8, stands a nearly vertical vein of quartz, which at this point begins on the east wall, at a depth of 200 feet below the surface, and widens downward, reaching a maximum of 125 feet on the 700-foot level.

Like the west vein, it is faced with selvages of clay. That on the east, parting it from the country propylite, contains the same rolled pebbles as were mentioned in the Belcher, which, through the whole lode, distinguish the east clay from the west selvage; the latter is drier, more uniformly pasty, and carries no pebbles. Ore was wholly wanting in the Crown Point workings of this vein down to 30 feet above the 500-foot level, where, 130 feet east of the shaft, and 60 feet south of its plane, a small silver deposit made its appearance, occupying 20 feet of the quartz body, narrowing as it descended, and entering it like a wedge. In the Yellow Jacket, 60 feet north of Crown Point shaft, on this same level, lying in similar contact with the east clay, was also a small body of workable ore, 30 feet long and 20 feet high. Above the sixth station this same body was sufficiently rich to be worked. A similar concentration occurred above the 700-foot level, and continued north through the Kentuck claim into the Yellow Jacket. On the 800-foot level the ore occupied three sheets in the quartz, thinning to mere edges upward, but widening downward, decreasing in richness until the ore was disseminated throughout the vein. On the 800-foot level the bonanza began to pitch to the north; on the 900-foot level there remained only 25 feet of ore, which in a few feet of depth ran into the Kentuck, leaving below this, as far as the deepest explorations have gone in the Crown Point, a vein of utterly barren quartz. All the western cuts from the low levels discover a large clay-seam, approaching gradually in depth toward the west selvage of the east vein. It is without doubt the same wall which, higher up, curves over to a horizontal position and terminates the west vein.

A considerable change takes place in the short distance of 270 feet, between the plane of the section just described and that through the Yellow Jacket south shaft; also on Atlas-Plate 8. The western vein has increased from 50 to an average of 110 feet wide, its west selvage maintaining nearly the same dip as in the Crown Point mine, but recurving slightly to the east. The eastern side of this vein makes a bold swell to the east on the 190-foot level, recurving to the west on the 360-foot level, and again widening out upon the terminating wall to nearly 200 feet. The ore, instead of being distributed equally through the whole of this large mass of quartz, is on a central zone or sheet about equaling the whole thickness of the vein in the Crown Point section. The

360-foot level was driven due west through this vein, and 120 feet west into the country-rock, which proved to be a metamorphic schist. The workable ore rises about 50 feet above the 190-foot level, and ends in the quartz like a wedge.

The whole east vein in this section has a greater inclination to the east than in the Crown Point: from the 200-foot level it pitches to the east at an angle of 50° with the horizontal. No ore was inclosed in it until 550 feet below the mouth of the shaft, where the silver deposit began on the east clay and widened downward, until at the 730-foot level it was 20 feet wide. On the 840-foot level, a little south of this section, the drift developed ore all the way through the Kentuck and the Crown Point; 600 feet north of the shaft, on this level, ore also occurs directly under the old north workings of the west vein. At the present deepest level the ore reaches from the Crown Point north line to the Yellow Jacket shaft, and, after a barren interval of 200 feet, continues 190 feet further north, with the breast still in ore. This is well shown on Atlas-Plate 6.

Passing now to the section through the Yellow Jacket north shaft, it will be seen that the west vein has almost disappeared and is only represented by a thin seam of quartz, eight feet thick, faced with thin layers of clay. The east vein, on the contrary, has increased extraordinarily. Its surface width is 200 feet, thinning down with irregularly curving walls to the greatest contraction on the 525-foot level, where it is only 45 feet wide, but rapidly makes in depth to the 700-foot level. Here it is singularly broken off by a dike of quartzose propylite. A clay-vein parts the dike from the quartz. When the working connections shall have been made between this point and the lowest level from the south shaft, the nature and extent of this intrusive porphyry will be understood; but at present little can be said of it. An air connection has been lately made between these points, developing, as was expected, the imperfect continuity of the quartz. Silver ore is confined to the zone from 30 feet above the Union Tunnel to 40 feet below the 530-foot level in the old works. It is hoped and believed that the most northern ore in the 940-foot level will rise nearly to the bottom of the north mine-works. There are two bonanzas lying in the same quartz-mass, separated by an interval of barren rock. They are, in fact, the southern ends of the Gold Hill bonanzas. Their upper outlines

are approximately the same, but the east body descends 200 feet lower than the west.

The next northern section is that through the Consolidated shaft, Atlas-Plate 8, where the east country propylite outlines the vein in a broad conchoidal curve, assuming the regular dip below the 420-foot level. The selvage of east clay, with its inclosed pebbles, which has been the partition between country-rock and vein-matter throughout the whole east face of the lode, here thickens to 30 feet. Its interior structure is partly a series of parallel plates and partly a compacted mass of conchoidal scales, which bear on their striated and scored faces the evidence of motion. The ore still shows its tendency to form in two parallel sheets with the addition of a connecting diagonal vein. Higher up, and inclosed in the same dislocated and shattered quartz vein, lies a narrow seam of ore, dipping to the west and corresponding in position and character to the west vein. It is believed that this is, in fact, its northern extension.

Continuing still further, the next diagram is a section on the plane of the Eclipse shaft. Here the east wall dips west from the surface to the 335-foot level, then curves sharply under, assuming the regular east dip. This wall is lined with the characteristic pebble-bearing clay, which thickens toward the south into the immense body described in the Consolidated shaft section. The quartz is more than ever shattered, and the ore dislocated and thrown into broken, isolated patches. The same western-dipping seam of silver ore was found, inclining from the surface 45° west, and was profitably worked out. Where the west wall would be naturally expected, as in all the country west of the Gold Hill mines, there is only a broken and decomposed mass of rock, showing evident solfataric action, and interlaced by an infinite number of fissures lined with clayey material and glazed with a coating of oxides of iron and manganese.

Next north is the important section through the Empire shaft. Here the east country-rock is much decomposed and reddened at the surface, but soon becomes homogeneous and normal in depth. The clay is well defined, thickening at the 328-foot level to 20 feet. Quartz lies next the east clay down to the lowest openings on the 1,084-foot level of the Empire-Imperial shaft. As in the north Yellow Jacket, the quartz, from an extreme thickness

on the surface of 200 feet, tapers around the swell of the east wall to about 40 feet on the 428 and 535-feet levels, widening again downward to 100 feet at the deepest drifts. The west vein cropped on the surface and continued west and down to 220 feet.

In the last three sections this west vein has only appeared as a seam of ore in the general quartz-mass with the east ore-bodies. This wide zone of quartz is broken and shattered into blocks, becoming more and more crushed, until in depth it assumes the sugary form. On the 328-foot level it is 50 feet wide, dividing toward the surface into three sheets, of which the western, or thinnest, rises 80 feet and ends. The middle one, 23 feet thick, reaches 70 feet above the 240-foot level, while the eastern seam ascends to within 150 feet of the surface. Through all of the upper workings down, at least, to 300 feet below ground, the quartz is stained with manganese oxide. This occurs in a thin coating and lining of the cracks. It is partly of the ordinary manganese oxide and partly hard manganese ore.

The Comstock lode, then, throughout this section, is walled on the east by normal feldspar-hornblende-propylite, which, near the surface, and more especially north of Gold Cañon, is earthy and tinted of every ochreous shade of red and yellow. The porphyritic texture is still traceable in the decomposed upper rock and becomes more and more apparent in depths where, below the line of atmospheric oxydation, the rock assumes its normal condition. Stringers of clay and minute veins of quartz thread the wall-rock in the neighborhood of the vein, and, near the 900 and 1,000-foot levels, gypsum accompanies the fissures, occurring in fibrous crystallizations, usually arranged diagonally across the cracks.

The nature of the west wall is somewhat problematical. Lying west of the west quartz vein, from the Empire to the Crown Point, is a confused mass of propylite and distorted metamorphic rock, fissured in every conceivable direction, and obscured by thermal action. Replacing these rocks in the Belcher, a mass of white propylite comes in contact with the vein and extends indefinitely downward. The western vein extends from the Alpha to the Middle Belcher, terminating from 300 to 500 feet on what is, in fact, the west wall of the lode. Every indication points to the belief that this singular horizontal clay curves downward and joins the east vein. Wherever explora-

tions have been pushed to the west and below it, no signs of a vein have been found; each tunnel has encountered western country-rock, altered propylite, metamorphic, (uralitic,) schists, or quartz-propylite.

Concerning the geological relation of the east and west veins, Raymond, (Report on Mineral Resources, &c., 1869, page 46,) says:

"*Sixth ore-body.*—The large body described as No. 4 of the Yellow Jacket, Kentuck, Crown Point, and Belcher, extended to the depth of 400 to 500 feet vertically below the surface, where a body of clayey matter, originating from a heavy dike of felspathic porphyry, cut it off very abruptly. In the Yellow Jacket, explorations were carried on for 100 feet vertically below this line, but without success in finding ore. In the Crown Point, explorations were made both eastward and downward; and the vein matter to the east of where the ore gave out was found to be replaced, frequently for a horizontal distance (east and west) of 150 feet, with various species of porphyry, of which felspathic porphyry predominated. As the prospecting work advanced eastward, the vein began to carry quartz again, and, about 450 feet east of the place where the ore was abruptly cut off, this quartz began to carry ore. Fifty feet further east, in the 500-foot level of the Crown Point, a very fine body of ore was discovered. West drifts from the first body to the west wall proved the ground to be barren. *This conclusively demonstrated that the vein matter had suffered a dislocation from west to east*, and the ore found east was locally termed the "East Vein." This body has thus far been explored and worked for a horizontal distance of 400 feet. It has its southern terminus about 200 feet south of the north line of the Crown Point; its northern limit has not yet been determined. Its upper edge is 75 feet above the 500-foot level of the Crown Point; it dips with the east wall slightly to the east, and inclines so decidedly to the north in depth that the 900-foot level of the Crown Point has not a trace of it, even at the Kentuck line. (The ore has therefore made 200 feet "northing" in 400 feet vertical depth.) The terminus of this body in depth has not yet been found. The Yellow Jacket explorations (850 feet vertically below the surface) show it still continuing downward and northward. In the Crown Point it is nearly exhausted."

Although agreeing with Raymond in every other particular of his excellent chapter on the Comstock ore-bodies, the writer cannot agree with his belief that the west quartz is a faulted mass from the east or main vein. First, because there are no signs of such powerful lateral movement through the propylite horse material lying between the two quartz-masses; on the contrary, the leading jointing lines and clay seams, with the exception of a single sheet in the north Yellow Jacket, are up and down. Secondly, if it had been faulted, the east vein would have been wanting east of it, which is not the case either in the Crown Point or Yellow Jacket. Thirdly, indications that this west fissure is independent of the main or east vein are present in the Eclipse, Consolidated, and Empire sections, where, cut through the

united mass of quartz, and entirely distinct from the east ore-body, is the northern prolongation of the west ore-sheet, terminated in depth with the same oblique clay-plane, which plane joins, as far as can be seen, the west selvage of the east vein.

The main east vein conforms closely to the curved conchoidal lines of the east country, and narrows from 200 to 60 feet, widening in depth again to 100. The surfaces of this quartz are never smooth, but fractured masses are more or less imbedded in the clay walls. This quartz is more and more shattered in depth, becoming altogether sugary below 500 feet, like that of the lower portion of the west vein. The red tint of the surface, given by percolations, extends only to the depth of 300 feet in the east vein, but descends along the clay-wall of the west vein to the 452-foot level. The east vein, in the deepest workings of the Crown Point, Yellow Jacket, and Empire-Imperial, still continues with only slight signs of diminution. An increased mixture of clay and small fragments of propylite is the only bad sign, and this, though usually a fatal indication, has not yet proven so either here or in the Hale and Norcross. At the south end of the 800-foot level of the Crown Point, the quartz begins to be cut out transversely by propylite; but after a brief interruption of 300 feet it continues southward for a short distance into the Belcher; see Atlas-Plate 12. Lining these two veins of shattered quartz are selvages of a plastic gray clay, formed doubtless of decomposed propylite. It is of a tough consistency, and when air is admitted by gallery or shaft it immediately begins to swell and exert tremendous pressure, forcing itself through the interstices of rocks, bending and breaking the most carefully laid timbers, and filling mine-openings with extraordinary rapidity. The average thickness of the east clay is two to three feet, but it expands in places to 30 and 40 feet. The clays of the west vein are rarely over two feet, usually less; they are darker in the region of the metamorphic rock, probably from the decomposition of magnesian and iron minerals. Those clays which mark long fissure-lines through the horse materials are of the same water-tight, tough nature. They render mining drainage extremely uncertain; for reaching a given level is no proof that all the region above will be drained, since the clays dam up within the limits of conchoidal fractures a series of independent reservoirs which can never be predicted.

Waters above the 800-foot level are usually about 70° F., which is also the average heat of the rocky material of the vein. In the 1,040-foot level of the Crown Point, and the lowest drifts from the Empire-Imperial, waters, apparently rising from below, are found of a temperature of 102° F.

The reader is referred to Atlas-Plate 6, for the arrangement of bonanzas. This Plate, on a scale of 200 feet to the inch, is a longitudinal elevation of mine-works, and is tinted with purple to indicate the silver bodies. In the southern part are the group of small ore-bodies in the single vein which traverses the Uncle Sam, Overman, and the Segregated Belcher. In the western vein first occurs the Belcher bonanza, of irregular, rounded outline; next north, after a barren interval, is the Crown Point west bonanza; succeeded again on the north by the oblique spur representing the west vein in the Gold Hill mines. In the east vein is the Crown Point bonanza, lying east of, and below the former. This is a wide-spread deposit, clouded irregularly through the region within the dotted line upon the Plate. After continuing down vertically to the 800-foot level, it pitches thence northward, and expands rapidly in the Yellow Jacket. In cross-section the ore of this bonanza shows a tendency to split into parallel zones in the vein, ending upward, like wedges, in the quartz.

In the great Gold Hill bonanza the mode of occurrence can be better understood by a glance at Atlas-Plate 6 than by a lengthy description. The quartz in the ore-bearing parts of the veins does not in any particular differ from that in the barren portions. It is usually either reduced to blocks which are crushed roughly together, or else shattered to a fine sugary state. There are portions, as on the 700-foot level of the Yellow Jacket and Kentuck, where it is a fine powder. So little compact, rocky quartz is there, that the ore has been wholly removed without blasting. Commingled with this sugary quartz are small, angular bits of propylite, and more or less clay infiltrations. The bonanzas, as defined, give, in one sense, an erroneous impression, their boundaries only representing the limits of the pay ore, on a grade rarely less than $20 per ton. Throughout the uncolored parts of the Plate, the quartz has only a small tenure of ore. The mineralization and probable origin of these bonanzas will be discussed at the close of this chapter. The Gold Hill bonanza descended from 250 to 550 feet, and although explorations have been pushed 500 feet further, the quartz is barren. In the Empire-Imperial lowest drift a

few little threads of silver were found, as is the case through all the quartz, but they led to nothing. The Yellow Jacket, and a part of the Kentuck, have now at their lowest level the only deep ore in the Gold Hill section. Regarding these several bonanzas as a group or family, it is noticeable that the deepest ore lies almost vertically under a point in their middle, and that north of this central line have been the longest and richest deposits.

THE VIRGINIA GROUP.—In the Virginia division the fissures have followed, first, the contact plane between the propylite and older syenite; and, secondly, have continued their northeast trend out into the propylite after the contact fissure bent to the west, and, still diverging at an angle of 50°, the eastern fracture has made a bold curve to the east, finally turning back again to join the west wall in the Gould and Curry ground. The first section on Atlas-Plate 9 is constructed through the Potosi south stope, almost on the plane of the Chollar shaft. On the level of the Potosi adit, 218 feet below the datum-point, the entire vein was one mass of quartz for a breadth of 280 feet. Above that point it divided into three spurs: one following the west wall upward at an angle of 45° to the surface, maintaining a width of 50 feet; the middle mass, curving upward, divides a great horse of propylite in two; the third, having a width of 140 feet, rises to its outcrop, separating the east horse from the east wall. From the adit the quartz descends about 500 feet to a point just below the Chollar-Potosi first station, or 669 feet below the datum-point. The west wall, wherever developed in this section, has a smooth, even face, and a regular dip of 45° east. The east wall is much more nearly vertical, and therefore converges into contact with the syenite. This junction, which is just below the the Chollar-Potosi first station, marks the termination of the wedge of quartz. A thin selvage of dark clay parts the vein from the syenite, and the ordinary thick, pebble-bearing clay lies continuously between the vein and its east wall. The quartz forming this immense body changes frequently in texture, and shows the great variation in dynamical influences which have modified all the Comstock materials. The western spur, which follows the west wall, is hard, blocky, and characterized by crystalline vugs, to a depth of 400 feet; the middle one outcrops but feebly, and is of a mechanical texture similar to the west; the east spur, on the contrary, more nearly resembles the crushed rock of the whole ore-channel. Both horses included between these sheets of quartz are wholly of propylite, and, as

usual, are intersected by clay veins, and are of a semi-decomposed, spongy nature. The whole mass of the lode here, both quartz and horse, is impregnated with iron pyrites, and near the surface all its cracks and faces are glazed with coatings of oxide of manganese.

Following the east wall, from the surface down 400 feet, is a body of ore which widens from a thin seam to 80 feet on the 218-foot level, and then narrows again to its lower termination. The greatest width of this is in the Potosi adit, and here, in its very heart, is a zone of barren red quartz, included after the manner of a horse. Below the 242-foot level the ore leaves the east wall, and is separated from it by a thin plate of dead white quartz. From the same level to the Chollar-Potosi first station, the white quartz gradually cuts out the red; in other words, the action of surface oxidation descended lowest upon the west wall, and gave out altogether at a depth of 400 feet. Below the junction of the walls, at 669 feet below the datum-point, the vein is entirely wanting, the propylite resting in almost exact contact with the syenite, the separating sheet of clay being almost as thin as paper. Explorations have been pushed downward to a depth of 1,408 feet below the datum-point without any signs of the lode making again.

The next section to the north, on Atlas-Plate 9, is through the Potosi shaft. Here the same general features are observable. The vein begins to branch upward at a somewhat deeper level, just below the 242-foot station, and, in consequence, the two horses descend further into the lode. There is also a greater expansion from east to west. The surface line following the incline of the hill gives 750 feet of outcropping material; the longitudinal width on the level of the Potosi adit is 400 feet; the vein also descends to a greater depth, the contact of the two walls taking place half way between the second and third Chollar-Potosi stations, or at a point 830 feet beneath the datum-point.

The ore, as in the former section, follows the eastern wall from the surface down to about 500 feet; it is, however, narrower, never exceeding 50 feet. From the 350-foot level down to the first Chollar-Potosi station, the quartz is separated from the west wall by a thin sheet of irruptive rock which, from evidence hereafter adduced, is considered to be a dike of andesite. As

in the last section, the lower portion of the quartz is white, and is parted from the red by a seam of clay.

Minor changes occur throughout the whole quartz-mass. They are usually traceable in a parallel arrangement of zones, which differ from each other in size of fractured blocks, in color, in amount of clayey infiltrations, and most prominently in their tenure of silver minerals. An interesting example of this is in the section now before the reader. That spur which follows down the east wall is charged through its eastern half with extremely rich silver sulphurets, the argentiferous portion being defined on the west by a thin seam of mixed clay, red ochre, and finely comminuted quartz. The quartz lying west of this seam is redder, firmer, and far less richly mineralized of the two. Upon descending, the partition line continues to separate the bodies down to the west wall, where it brings up against the black (andesite) dike. Below the 290-foot level the east body loses its red color.

The west wall preserves its old dip, but has not so perfectly even a surface. It has already begun to bend westward. The same deep explorations have been continued below the termination of the vein, and there are still no signs of its renewal. From the Bullion, then, to this point, the lode is an immense wedge of quartz, widening as it rises toward the surface, until, on the 242-foot level, it divides into three bodies, which continue to the face of the hill slope, occupying respectively the west side, the middle, and the east wall, and embracing two large horses of propylite. It was shown that the bonanzas on the Gold Hill northern sections are confined to the east wall. The evident parallelism of arrangement between them and the two last considered sections is an interesting instance of the unity of plan throughout the lode.

Lying to the north of the Chollar-Potosi is the Hale and Norcross claim. A section through the plane of its shaft is next given. It will be noticed that a marked change has taken place in this short distance. The old wedge of quartz reaches down to about the same distance, but the horses have penetrated to a greater depth, cutting off entirely the middle and east quartz-spurs on the lower levels. The clay wall which defined the eastern limit in Potosi ground is still apparent on the east side of the east red quartz, but an entirely

new fissure has developed itself to the east of the old one. Starting from the surface trace of the east clay, the new fissure descends nearly vertically to the 400-foot level, where it curves rapidly to the east, projecting indefinitely downward at a general dip of 40°.

In contact with the east wall, downward from the 480-foot level, has existed a vein of white quartz, having an average width of 70 feet, but contracting on the 750-foot level to 40 feet, and again on the 1,100-foot level pinching to about the same breadth.

Where the quartz first made its appearance it curved eastward, approaching a horizontal position, and including a large body of ore.

This ore has occupied a zone on each side the quartz, whose central portions have never carried a workable percentage of silver. The same irruptive dike which was noticed in the middle levels of the Potosi section occurs in the Hale and Norcross, rising to different heights along the west wall, appearing with more or less regularity down to the 1,000-foot levels. From the 535-foot station down to the 750, a seam of quartz crosses it diagonally. The red vein, forming the western mass and corresponding to the great body in the Chollar-Potosi shaft-section, is here never richly mineralized. In the early days of Washoe mining it was rejected altogether, but under the present stimulus of cheaper costs of mining and milling it is yielding a fair profit. The character and average silver tenure of these poorer parts of the lode are the most difficult points to consider; all ore selections are made by the miner's eye, the constantly changing percentages in the rock defying a general estimate. The only true value is gotten by mill returns.

By referring to Atlas-Plate 11, it will be seen that the section on the 331-foot level shows the red vein and the remarkable fact that it leaves the east wall and traverses the horse material, joining the west wall at the extreme western angle of the recurve. The west country in the Hale and Norcross inclines to the east at a rather gentler angle than in the more southern claims. Quartz, propylite, andesite, and clay are all alike impregnated with brilliant crystals of iron pyrites.

The three sections of Atlas-Plate 9 illustrate every important fact in the southern half of the Virginia group excepting the existence of two syenite horses, which appear on Atlas-Plate 11. In the Bullion and the southern part

of the Chollar-Potosi, in both sections of this Plate, may be seen lying upon the west wall a considerable mass of syenite, defined upon the west by a clay. These bodies are unlike the west country syenite in that they are decomposed by chemical action, usually, it is true, much less than the propylite material, yet so far as to lose their coherent texture and become softened and, in a measure, plastic.

The ore-bodies south of the Hale and Norcross line are confined to levels within 500 feet of the surface. The most southern, or Blue Wing, is cut in the Potosi-south-stope section and may be also studied on Atlas-Plate 4, where the expanded levels overlying one another are horizontal cuts of its most prominent portions. On Atlas-Plate 7 it is shown in vertical elevation directly back of the Potosi shaft. With a width on the surface of 160 feet it descends to 360 feet. As was remarked of the Gold Hill bonanzas, these limits only indicate the extent of ore that carried not less than $25 to the ton. A very large portion of the vast quartz body lying to the west, north, and south of this stope contain sufficient silver to warrant working at present labor prices, and in the course of the next two years the boundaries of the bonanza must be considerably enlarged. Next north of this lies the Potosi bonanza, a large and valuable body which, on the level of the Potosi adit, extends from north to south 450 feet. Its greatest downward extension was on a line dipping toward the south and extending from its upper limits 600 feet.

Lying west of this in the upper levels was a small, irregular body, also laid down on Atlas-Plate 7. A cross-section through the Hale and Norcross lower works, from the 787 to the 1,338-foot level, Fig. 3, Atlas-Plate 12, shows the arrangement of the quartz and ore at the present bottom-level. The seam which had followed the east wall to the 750-foot level leaves it and curves downward into the middle of the vein. A deposit of ore occupies its central position down to the 1,000-foot level. On the 1,170-foot level a thin, limited bunch of silver edged its western termination. At the 1,000-foot level a new body of quartz made its appearance in the eastern wall; its position is shown on Atlas-Plate 12. This important new body carries its ore on the eastern side, and includes within its crushed mass brecciated bits of propylite.

The section on Atlas-Plate 10 through the Savage stopes shows, first, the gradual giving out of the red bodies near the west wall; and, secondly, a rapid rising toward the surface of the east white body. The east wall has assumed a double conchoidal curve, presenting a decided convex front to the lode down to 210 feet below ground; then reversing, throws eastward its curve with the concave side turned toward the vein. In these bends are two bodies of quartz, tapering together and giving in section the form of two crescents. The section of these bodies and the subdivision of fissures in depth afford one of the most interesting examples of complicated structure in the whole lode. The two bodies of ore are still distinct, but instead of the separating space of barren quartz before noticed, they have included a propylite horse. The eastern side of this horse is largely decomposed, resulting in a thick band of clay 16 feet wide. Traces of the old west fractures may be seen in the north Potosi adit in two small filaments of red quartz which cross it in an inclined position.

The east veins at this point were barren to the bottom of the first great curve; from thence downward they were nearly filled with ore until they began to converge. From there the sheets of quartz rapidly came together, and, becoming largely intermingled with fragments of country rock and clay, gradually lost their tenure of silver, and, below the station, narrowed to their extreme thinness, ending, at last, in a mere loose belt of clay.

The arrangement of these quartz-masses along the east wall and concentrically within it, are excellently shown on the lower section of Atlas-Plate 11. The true east wall completes a semicircle to the east. From the Chollar line to the Gould and Curry, it has no quartz in contact with it. The main ore-channel diverges from the wall 100 feet north from the Norcross south line and follows its curvature, but lies usually about 100 feet within it.

The ore through the North Norcross and South Savage was a zone varying from 15 to 35 feet in thickness, lying for the most part on the east side of the quartz. The quartz itself averaged 50 feet wide, and was uniformly of the sugary-fine variety. Concentrically, and to the west of this, lay a fine seam of ore-bearing quartz about six feet thick. After pinching to a mere thread opposite the E-Street Savage shaft, where the greatest amplitude of the

Virginia curve occurs, the main quartz quickly expanded northward to its old dimensions, carrying an immense bonanza.

Comparing the two bonanzas north and south of this point, Atlas-Plate 7, it will be at once seen that the southern is more regular in form, while the northern is larger and more important.

Lying east of this North Savage body, and confined between the 661 and 768-foot levels below the datum-point, there occurred a more eastern quartz-body, lying in contact with the actual eastern wall. This so-called "Potosi strike" is shown on Atlas-Plate 7, relieved with a darker tint against the Savage bonanza. Its horizontal section, on the plane of the Savage seventh level, is indicated on Atlas-Plate 11. Lining this body on the west, and defining it from the curved propylite horse, was an immense vein of clay, 18 feet in thickness. On the Savage seventh station, this quartz-body has entirely given out.

A section on the Savage north line is given in Atlas-Plate 10, showing the bodies of quartz filling conchoidal fissures, whose convex sides are to the east. The red quartz descends to a depth of 500 feet, and is firmer and less easily mined than the parallel zone of white. The eastern body is wholly of white quartz, and contains its ore in a limited segregation in the very heart of the sheet. An important fissure, still further to the east, makes its first appearance in the Gould and Curry second station, 625 feet below the datum-point.

Turning now to the section through the Bonner shaft, Atlas-Plate 10, a new wedge-like body of quartz is seen lying upon the syenite in the upper levels, known as the Eldorado vein. This converges at the depth of the Eldorado adit with what was the larger body of the Savage north line. This connects in depth with the eastern vein, and forms a continuous mass of quartz, widening to 170 feet. From the outcrop 310 feet down, is contained a very remarkable bonanza, whose peculiar section in the Gould and Curry is seen on Atlas-Plate 10. A singularly complex figure, it is really two vertical sheets, connected near their bottom by a diagonal joining-seam, similar to that noticed in the northern Gold Hill workings. Here was the richest and most productive of all the Comstock ore-ground. For five years the chambers in this bonanza steadily yielded an immense revenue; and even

now the only supply of the Gould and Curry is the formerly rejected portions of this body. The horse material enters the body of red quartz in two wedge-like masses, closely resembling in form those of the section through the Potosi shaft.

It is instructive to compare these two sections. In each the red body follows the west wall, and toward the surface thrusts up a central spur, outcropping in the middle of the vein. Following the western wall to the surface is a lesser spur, which, in the Gould and Curry, branches from the large mass just below the Mount Davidson adit. In the Chollar-Potosi, as already shown, the eastern is the larger and ore-favored sheet; in the Gould and Curry on the contrary, the central mass largely predominates, and contains all the ore. From the South Chollar ground to the North Gould and Curry, is an elliptical chamber, widening in the middle, as was shown on the Atlas-Plate 11, to 900 feet. It will be seen that in this great central chamber of the Comstock the quartz has made its appearance in two sheets, occupying positions successively lower and eastward; following the east wall for a certain depth, and then diverging in a more vertical course, to be replaced by new east bodies, which in turn fork downward into the vein. The southern half of the eastern curve of the east wall is about in the plane of the long fissure from the Bullion to the North Chollar line. The quartz has a tendency, throughout the whole curve, to swing from the east to the west wall, undoubtedly given by the underlying syenite, which in the north part of the chamber juts boldly to the east.

Atlas-Plate 11 consists of two horizontal sections of the Virginia chamber: first, on the level of the North Potosi tunnel, 331 feet below the datum-point; secondly, on the plane of the Savage second station, 625 feet below the datum-point. Both these sections are on levels which are remarkably well known. It would also have been difficult to choose two planes where more interesting conditions could be exposed. In the first is seen the two Chollar-Potosi quartz-masses, together with their included propylite horse, curving over to the west wall, where, against the right angle of syenite, they eventually cease. The Savage-Gould-and-Curry quartz sheet is also seen to part, its larger mass traversing the middle of the lode and ending, like those of the Potosi, in a mere plate upon the west wall. The second or lower section is chiefly

interesting where it shows the Bullion and the Chollar syenite horses, and the remarkable manner in which the interior structure-lines of the North Savage mine conform to the sudden change of direction of the west wall. The reader will find in the three transverse clays which mark the west wall, the termination of the ore-bearing quartz, and the immense seam which bounds the Potosi strike, most interesting examples of the power of a rigid wall over less coherent materials.

Fig. 2 of Atlas-Plate 12 shows the aspect of the chamber on the present lowest levels. In the Chollar-Potosi the vein is entirely wanting, the walls of propylite and syenite being simply parted by an almost imperceptible sheet of clay. The quartz-body which begins in the North Chollar, and extends for 200 feet into the Hale and Norcross, along the west wall, is of white crushed rock, mixed with clay and porphyry, and barren of all silver.

The three bonanzas described in the Chollar-Potosi, see Atlas-Plate 7, are the uppermost limits of the fan-like expansion of the whole silver system of the chamber. The Hale and Norcross bonanza is about equally divided between the Norcross and Savage mines. Its upper level was 355 feet below the surface, and it extended to the 850-foot level, terminating in barren quartz. The average thickness was about 15 feet; its greatest width of 50 feet was on the 535-foot level. Next below, a little further east, lies the second Hale and Norcross bonanza, the present lowest ore in this group. The Savage bonanza rises toward the north, filling the same sheet of quartz from the 868-foot level to the 486, inclined constantly to the north, and reproduced still further toward the surface by the great Gould and Curry bonanzas. These two bodies have a combined length on their greater, or inclined, axes of 800 feet, and an average horizontal length of 300 feet, while their width across the vein increases from 20 feet in the lower Savage bonanzas to 100 feet in the upper levels of the Gould and Curry.

Chemical decomposition has progressed somewhat further than in Gold Hill; the lithological structure of the propylite is rather more obliterated, the whole mass tending more into clay.

As was remarked of the Gold Hill workings, this clay matter possesses wonderful expansive power. The timbering and galleries have been crushed with an almost incalculable force, in several instances requiring greater expenditure to keep the drifts open than for the original cost of construction. Where

it has been necessary to fill large chambers to prevent serious accidents from caving in, as was the case in parts of the Savage and Gould and Curry mines, rooms were opened in the thick bodies of clay, and an endless supply obtained by its expansion. In the region of the Potosi strike, a chamber about twelve feet high and fifteen feet across was opened in clay, which, on exposure to the air, immediately began to swell and to flake off in conchoidal scales from a foot to two feet in size. Two men wheeled these as fast as they fell from the roof of the excavation, and dumped them into the open stopes. For weeks the falling clay gave them ample material, the size of the cavity scarcely changing meanwhile. After filling the stopes the chamber was abandoned; and when next visited, at the end of a few weeks, was found to have filled itself solid.

THE OPHIR GROUP.—Atlas-Plate 5 comprises all of the materials that can be assembled of the region lying between the Gould and Curry and the northernmost workings of the Ophir. This, in reality, indicates the northern limit of the productive lode. Continuing northward upon the slopes of Cedar Hill, there are indeed several claims in which the quartz is still developed, carrying small quantities of silver and gold, but so far nothing that can be called a bonanza has been found. The Sierra Nevada, in its uppermost levels, contains fragmentary masses of blocky quartz impregnated with native gold, closely resembling the California auriferous quartz. Directly west of it, and high upon the slope of Cedar Hill, gold recurs in the Sacramento mine, which perhaps is the Sierra Nevada sheet, although more probably it lies behind that body. Still further to the north of this, the Utah and Allen are unquestionably parts of the same lode, but in an economical sense have proved almost valueless; and their explorations are too limited to throw any additional light upon the mode of occurrence of vein-materials.

From the Gould and Curry to the north line of the Central the quartz-bodies continue; but, instead of being charged with the characteristic silver ore, contain bonanzas of base metals; galena, blende, and iron pyrites predominating. The 600 feet lying directly north of the South Ophir mine was at one time the richest and most productive portion of the Comstock. This highly complicated region is well shown on Fig. 4, Atlas-Plate 12, which is a horizontal section upon the level of the Union Tunnel, 270 feet below the

datum-point, and extends from the Sides through the productive part of the Ophir. It will be seen that this chamber contracts at the north end of the Ophir; and if the walls retain their present direction for 200 feet further north they will come again into contact and form the north limit of the Ophir chamber. From the south, the west-wall syenite continues to about the middle of the Central Number 2 claim; from that point northward, the west wall is of propylite—a dense, heavy rock, containing an unusually large proportion of hornblende, and frequently much decomposed and interlaced by filaments of quartz. The east wall here, as everywhere, is of the normal porphyritic propylite. It is defined by a very heavy body of clay. Lying next this seam is a sheet of quartz, varying from 6 to 100 feet in thickness, known as the white vein. It was here, in the early days of Washoe mining, that the highly crushed quartz was first found, and, from its position, came to be called the Ophir quartz. In this, for 200 feet of longitudinal extent, occurred the great Ophir bonanzas. Lying west of the quartz, and defined from it by the usual sheet of clay, was a propylite horse, remarkable for its unusual thinness and its great length of 1,100 feet. It is rarely over 20 feet wide, although in the South Ophir it once reached 35 feet. This horse, from the Union Tunnel level, thins downward until it terminates in a mere clay vein, which, for a considerable distance, separates the white quartz from the red seam, which lies directly to the west of the horse, but, on descending, the clay ceases, and the two quartz-bodies lie side by side. Next west of the porphyry horse is what has been known as the red vein, or hard quartz. It has about the same thickness as the porphyry horse, and extends from 300 feet north of the north Mexican line into the Gould and Curry. It is hard, blocky, filled with crystalline vugs, and differently charged with minerals from the white vein. West of this, and separated from it by another clay seam, lies the great Ophir horse, a mass of clear propylite, averaging 125 feet in thickness, and extending northward to the end of the chamber, and south into the Sides claim. This mass, of 1,100 feet in length, thins as it descends, meeting the west wall and cutting off the further continuance of the so-called Virginia vein, lying west of it. In the Ophir and Mexican a limited body of white quartz lies between the Virginia vein and the great Ophir horse. It terminates on the Union Tunnel level, at about the southern line of the Ophir. This quartz contains some ore,

and resembles the sugary variety far more than that of the Virginia vein, which it touches. The latter mass is entirely barren, and possesses a fissile, almost schistose structure. Little or no silver occurred in it, and its barrenness was only occasionally varied by accidental specimens of gold.

Upon Atlas-Plate 10 is a cross section through the Mexican mine, on the plane of that company's shaft. The west wall here, of propylite, descends at an average eastern dip of 47°; the Virginia quartz sheet, 50 feet thick, follows it down to the seventh level, from thence narrowing to six feet on the tenth station. As usual, the east fissure presents toward the vein a conchoidal curve, joining the west quartz-body on the eighth station, 598 feet below the datum-point. In cross section the quartz which follows the east wall is of crescent shape, 40 feet wide on the fourth station, tapering to a mere blade at the surface and a narrow edge on the seventh station. This body was charged with the celebrated Ophir-Mexican bonanza. Eighty feet west, and lying quite concentric with this, is a second thin sheet of quartz, curving down and terminating on the west wall, a little above the seventh station. The main east vein was of the typical ore-channel quartz, the thin middle sheet red and blocky; while the heavy Virginia body, lining the west wall, was of fissile gray blocks.

Fig. 1, Atlas-Plate 12, shows the Ophir-Mexican bonanzas. In the upper and north portion it will be seen that a nearly circular body lay concentric and to the west of the main deposit of ore, overlapping it a little toward the north. This western body, occupying the thin seam seen in the cross section, extended 300 feet from north to south, and 250 feet in depth. The outlines of the main eastern bonanza are very curious. From a width of 500 feet on the surface, it descended with a general triangular outline to 675 feet in depth, the northern boundary being more defined than the southern; the latter line recurves toward the center of the bonanza. Near the lower extremity a barren portion occupied the middle of the deposit, extending from the Latrobe adit down to 30 feet below the eighth station. The bonanza gave out at a point indicated upon the cross section, and explorations were carried to a considerable distance below without resulting in any favorable developments. The company are now engaged in sinking a new shaft, several hundred feet to the east of their old works, and will soon attack the lode by very deep levels.

## SECTION III.

### GENERAL STRUCTURE AND MODE OF OCCURRENCE OF THE COMSTOCK LODE.

Fissures.—We have now completed a sufficiently detailed examination of the interior structure of the lode to convey to the reader a fair idea of its materials and their mode of arrangement. The minutiæ of description might have been multiplied to an indefinite extent, each separate mining-claim furnishing ample detail for an independent treatise; but, in order to compress this account within as narrow limits as possible, the majority of the minor details have been omitted. It is proposed now to review in a general way the interior conditions of the lode, assembling the notes in a somewhat systematic manner. In preparation for this, the reader is recommended to make careful examination of the Atlas-Plates from 2 to 12.

First will be considered the system of fissures. In the Gold Hill part of the lode there are three distinct lines of dislocation, which define the leading outlines of the lode. They are, first, the two crevices which diverge from a common surface-line and project downward through the propylite; and, lastly, the third fissure which, after indistinctly traversing the disturbed and altered west country-rock, advances eastward in a nearly horizontal position, cutting off and terminating the westernmost of the two diverging fissures, then, continuing still further eastward, gradually bends to a steep pitch, and in depth communicates with the eastern fissure. Below 1,200 feet, then, the Gold Hill division will be but a single steeply-inclined vein. These three fissures are never planes, but present toward the lode a series of undulating convexities. As a group they trend with a certain general parallelism, occasionally converging toward each other, and in the case of the Gold Hill mines bending westward concentrically around Gold Ravine. The most southern direction of the group of fissures is north 28° east. After continuing this course, to the northern part of the Yellow Jacket claim, they sharply recurve round the cañon and continue to the Bullion, with a direction slightly west of the magnetic meridian.

From the Bullion to the point of greatest amplitude of the Virginia

chamber they trend north 28° east, or parallel to the south Gold Hill trend. From this point they stretch northward into the Consolidated ground, converging from a wide separation in the Savage, the general axis of the lode making a course of north 20° west. In the Virginia division, instead of the simple arrangement already noticed in that of Gold Hill, there are introduced two new features. First, the wide divergence of the walls, forming an elliptical chamber, whose longer axis is 3,000 feet by a short axis of 800 feet. Secondly, instead of one eastern fissure, marking the position of the ore-channel, is a series of four and sometimes five concentric east fissures, which separate the region of the ore-channel into numerous communicating veins. The west or contact fissure, continuing downward at a regular and uniform angle, is in depth joined by the fissures of the ore-channel from its two extremes, nearly to the middle of the chamber. At the farthest eastern amplitude these fissures, instead of shutting down into contact with the west-wall syenite, as they have done in the north and south portions of the opening, break off more and more to the eastward, curving gradually into approximate parallelism with the west wall. Additional fissures constantly make their appearance in the middle deepest point occupied by the Hale and Norcross mine, the ore and quartz retaining their normal relation to the east fissures. There is little doubt that the South Savage and Hale and Norcross mines are working down into a deep chimney or vent, through which have ascended the vein-materials and their metallic contents. They have passed what may be called the bottom of the gash, and were fortunate to find themselves located on the plane of the true deep-seated fissure. Where a series of vertical gashes penetrates through the overlying material to an inclined fissure, it would be strange if there were not several vents connecting with the deep-seated crevice. There are not wanting strong indications that the Hale and Norcross is now developing one of these chimneys, and the prospects of continued ore-product are quite flattering.

North of the elliptical chamber the conditions are for the third time novel. The west inclined fissure maintains its course, with a gently undulating surface, as far north as explorations have been pushed. The east ore-channel curves again to the east, embracing two more chambers of far less

importance and lateral extent than that of Virginia. The wedge-shaped surface expansion of the lode is in this region gashed down in a series of parallel fissures, dividing its material into thin vertical plates, separated from each other by immense developments of clay, and several quartz veins of remarkable continuity. North of the Ophir contraction the same parallel system opens up to the northward, and, in the region of the Sierra Nevada and Sacramento, prominent plates of quartz traverse the front of Cedar Hill, and penetrate downward as deeply as the excavations have gone. The peculiarities of the parallel plates of quartz and horse material in the Ophir Consolidated chamber are, first, their extreme thinness, and, secondly, their habit of curving sharply to the east and west, producing in the horizontal section a wrinkled and twisted outline.

That part of the lode in which the fissures are best understood is the Virginia division, where the solid front of syenite forms the western wall. To the south of this the west wall is still somewhat problematical, although the prominent clay-vein, which has been considered as limiting the lode in a westerly direction, is in all probability a true wall. North of the syenite the wall of propylite is a mere continuation of the syenite conditions, both of inclination and undulation of surface. From the position and relation of rocks, and the fact that the west walls north and south of Mount Davidson are, in all larger characteristics, simply repetitions of the syenite form, it is believed that this mass of Mount Davidson has been the most powerful agent in determining the position and character of the Comstock lode. When the mountain chain was subjected to a series of longitudinal strains, which resulted in the system of andesite dikes, it was natural that this rigid mountain spur should oppose an immense resistance to the dislocating force, and no place offers such conditions of easy fracture as the contact plane, between the ancient and deeply-bedded formations, and those later and less coherent eruptive rocks which have been superimposed upon their bases. Accordingly along this important junction occurs the relics of a dike of andesite, which seems to have been the first foreign substance to invade the contact plane and start the system of intruded materials, which has finally resulted in the Comstock lode. The general mode of occurrence of andesite, noticed in this district, proves conclu-

sively that the period of their outpouring was not a single eruption, but that they were ejected through a considerable period, successive flows overpouring the cooled and solidified products of the first eruption.

The west fissure is regarded as a rupture of the crust, caused by the earlier andesite disturbances, and to have been projected north and south, chiefly governed in position and inclination by the strain which the heavy syenite mass induced. Contemporaneously with this, or at all events with the earlier andesite fractures, has occurred the series of steeply-curved fractures, forming the connected ore-channel and east wall.

Throughout Gold Hill the east and west walls approach each other, until the vein in depth becomes a simple single mass of vein-material, included between two walls. In this section there are no grounds for predicating either a giving out or a permanent disappearance of the vein. It differs in no important particulars from others, which have continued indefinitely downward, and whose structural lines are supposed to penetrate the solid crust of the earth to immense depths. In the middle, or Virginia section, the relation of the east and west fissures is such that only the most central portions can continue to a great depth, since the eastern or steeper crevice terminates evidently against the western wall. Explorations have proven that for several hundred feet at least the vein is wanting, and there are no strong indications of its ever reappearing. It is left for the central point, occupied by the Savage and Hale and Norcross mines, to prove by further explorations whether the quartz-body in their lowest levels is indeed the top of a deep-seated chimney, or whether, like the other mines in this group, they are approaching the termination of their vein. Two strong reasons point to the conclusion that they have reached the deep vein. First, the series of fissures, instead of shutting sharply down upon the syenite, has gradually broken and curved into approximate parallelism with the west wall. Secondly, it is difficult to conceive how such enormous masses of mineralized quartz could have entered the upper fissures except from some deep-seated source, and taking this for granted, there is left no other point of connection with the subterranean laboratory. In the northern region explorations have not penetrated deeply enough to afford the data for a well-grounded opinion, as to the probable nature of the fissures in depth. But it may be said that no conditions are

known which would firmly preclude a belief in the continuance of both quartz and ore in depth. Only extended search, however, can determine the points where the wedge closes and where the deep-seated vein exists. The example of the Virginia chamber is remarkable, in that it affords an immense longitudinal expansion of vein-material and almost unprecedented distribution of bonanzas, with only the single, narrow, downward connection which we find now in the Hale and Norcross mine. It is possible, therefore, that the Ophir Consolidated chamber may likewise terminate downward in a single chimney, through which have arisen the varied solfataric products.

Horses.—Between the fissures whose position and relation have now been indicated lie the series of included fragments of country-rock, or horses, with which the reader is made somewhat familiar by a detailed study of sections. In the Gold Hill division of the lode there is but one main body of this character within the lode. That mass of white quartzose propylite known as the Hawk-eye horse, is in reality a portion of the country-rock, or rather, to speak more correctly, is an intruded mass which lies between the lode and its west wall, lined on either side with selvages of clay, so that it may be, by a stretch of meaning, considered either as a horse or as a part of the west country-rock.

North of the Middle Belcher, however, and continuing from that point to the north line of the Empire claim, is a single included mass of propylite, which has been fractured from the east wall, and occupies the whole middle ground of the vein. Its general shape, like most of the other horses, is that of a long wedge, with its point turned downward toward the intersection of the east and west clays. It is 2,500 feet from north to south, with a transverse expansion on the 400-foot level of about 400 feet, and descending to a probable average depth of 1,300 feet. Although a single general mass, and well defined by prominent walls of clay, it is nevertheless greatly subdivided both by immense conchoidal fractures and by a system of lesser fissures which interlace it in every possible direction, cutting it up into blocks.

In the north part of the Bullion claim the single vein of quartz, which occupies nearly the entire breadth of the lode, opens toward the east, and leaves room between its mass and the syenite for two limited horses which have fallen in from the west country. With the exception of certain indistinct bodies in the Gould and Curry, these are the only well-defined syenite masses

included within the lode. Like the propylite horses, they are subdivided by a net-work of unimportant fissures, and rendered somewhat plastic by the ordinary solfataric action; but they have not arrived at the same state of chemical decomposition which characterizes the rest of the interior of the lode, nor do they show anything like the tendency to become metamorphosed into clay, which is everywhere to be noticed in connection with the propylite alterations. They are limited in size, as will be seen on Atlas-Plate 11, and it is a very notable fact that they lie to the west of the andesite dike, which shows them to be more properly portions of the west country, segregated from the main rock by a simple sheet of clay; however, the west clay so evidently surrounds them that they can but be considered as true horses.

In the Potosi the immense quartz-body, which, south of the plane of the old Potosi shaft, uninterruptedly fills the fissure, branches as it extends northward, and includes two considerable masses of propylite. The longitudinal dimensions of the westernmost are 700 feet, with a transverse width of 280 feet on the surface, and a greatest depth of 210 feet. North of this point the great Virginia chamber is filled from the region of the ore-channel to the west wall by a mass of propylite 800 feet across. This great horse terminates on the north in the Gould and Curry, being cut out by the east quartz, which swings across the lode and unites itself to the west wall. The bottom of this horse is not yet reached; for at the lowest works of the Savage and Hale and Norcross mines there is still a considerable distance from the east quartz to the west wall. As was shown when studying the details of this region, the ore-channel, instead of being a single sheet of quartz, as is the case in the Ophir and Gold Hill groups, here occupies a complicated zone of fissures, and the masses of quartz and sheets of clay subdivide the propylite materials of this zone into a group of horses, whose minute details of form can only be understood by closely examining the sections.

From the north point of the Gould and Curry through the Consolidated claim, and even beyond the northernmost workings of the Ophir, the quartz walls are separated by two remarkable horses. The longitudinal extent of these masses is about 1,500 feet. The eastern one, which separates the Ophir quartz from the red body, has an average breadth of 50 feet, and penetrates into the lode from the surface to a depth of 580 feet; the western, or great

Ophir horse, more than three times the thickness of this, extends along the west side of the red vein for 1,500 feet, and descends to a depth of 460 feet beside the Virginia quartz.

More than nine-tenths of all this horse material is of propylite, consisting simply of immense slices cut off from the overlying country, and separated from each other by parallel, longitudinal fissures. The great horses are shattered through and through, but even in the lesser lines which subdivide them may be traced, first, a general parallelism with the trend of the lode; and, secondly, a tendency to break concentrically with the curves of the east wall. The lesser of these horses rest frequently throughout their whole length in quartz, but the larger ones invariably touch the west wall at one or two points, and are sustained from falling laterally, by contact with each other and by the solid walls.

The fissure and horses together, for the one is a complement of the other, give a complete idea of the larger dynamical results. These long, thin wedges have slid down on one another, and, crowding together, touch with their lower edge the west wall. In this tremendous dislocation have been opened seams and chambers, of which the larger have been filled with quartz and the lesser densely packed with clay. Beside these larger horses no considerable chamber of the vein is without its freight of small fragments. The west quartz contains throughout its whole extent angular masses of syenite and propylite, varying from the size of a hen's egg to a foot and more in diameter. In these fragments there is not the least sign of decomposition. The feldspars and hornblendes are perfectly preserved, the edges sharp as if recently fractured, and every appearance compels the belief that they are quite unaltered. This is the more remarkable, since they are found in a material whose very existence in a fissure is proof of an aqueous if not solfataric origin. These included fragments are usually the starting places of quartz crystallizations. They lie chiefly in the upper 300 feet of quartz, gradually diminishing in frequency in depth. In the larger fissures toward the east, both those which are filled with quartz and such as are chiefly lined with clay, may be found immense numbers of small propylite fragments. Where quartz-bodies in depth approach the contact of the two walls, or, in other words, as they begin to thin toward their own termination, the quartz becomes more and

more intermingled with these minute fragments of propylite, until they finally occupy the entire zone, and in their turn give place to the clays.

Clays.—The clays, so constant an accompaniment of all lines of dislocation throughout the lode, are formed, as will hereafter be seen, from the decomposition of propylite rock. Those clays, lying upon the syenite front of Mount Davidson, are far more the result of propylite decomposition than of the syenite. Syenite itself produces but little clay; and wherever a sheet lies between two masses of that rock it is of extreme thinness, and of a dark, earthy nature, possessing none of the remarkable chemical and physical properties of the other Comstock clay. Lying along the entire east wall is a continuous sheet of at least 20,000 feet in length; the average thickness may be safely estimated at two feet. Wherever the wall presents to the west a very sharp conchoidal curve, and, in general, wherever abrupt turns are made, the clay thickens to a great extent. Such notable examples as that in the Consolidated shaft, the Empire section, the point, shown on Atlas-Plate 11, on the east wall of the Savage, and the breadth described in the Palmer shaft of the Ophir, are its extremes of thickness; but many places occur where it attains a width of eight and ten feet. The interior structures of these thick, pasty bodies vary curiously with their position; those which accompany sharp turns are ordinarily subdivided into flakes, while the straighter sheets are cleavable into parallel plates. The characteristic of the east clay is the pebbles of smoothly-rolled quartz which it contains. No one of these pebbles, so far as examined, and observations have been made from the Ophir to the Crown Point, ever contains a particle of silver. The west clay, equally continuous with the east, is less dense, thinner, never charged with rolled pebbles, and lacks the remarkable property of expansion which the east and interior clays possess.

Whoever undertakes to study the interior systems of clay sheets which intersect the horse materials, will find that their continuity is almost impossible to trace out. After continuing in a given direction for several hundred feet, they will break sharply off at an angle and fault to the right or left, losing themselves in interminable zigzags through the horses. There is no unraveling the relation of this network of veins; and upon the diagrams the writer has been careful to have recorded only those sheets whose continuity has been identified beyond a doubt.

QUARTZ.—A third, and by far the most important, series of vein-materials are the bodies of quartz which everywhere throughout the lode fill the larger openings. In Gold Hill a single but imperfectly known quartz fills the lode from the southernmost workings up to the Middle Belcher. From this point to the northern limits of the Gold Hill group the two bodies diverge from the surface and fill those fissures already described. North of Gold Hill, through the Alpha and Bullion, there is again but one vein which, in the Chollar, widens to the northward and finally splits into three forks, separating and inclosing the two great propylite horses, and finally curving to the west, gradually converging and terminating upon the syenite. Following the zone of eastern fissures are several masses of quarts, arranged concentrically within the east wall. As in the Chollar, this mass, after thickening rapidly toward the north, diverges and again includes two horses, and following still further the Chollar example, its two spurs bend across the lode and terminate upon the west wall of the Gould and Curry. North of this point are three veins of quartz, which make their appearance successively further to the west and north. The easternmost of these is an immense sheet, rarely less than a hundred feet wide, continuing along the east wall to the northern limits of the Ophir. The next is a red body, which extends from the Gould and Curry, also through the Ophir, lying between two horses of propylite. The third, or Virginia vein, as it was called in early days, outcropped back of the Consolidated claim and extended indefinitely northward, not improbably connecting with the Sacramento works upon Cedar Hill. Like the horses these masses vary from a few hundred to 2,000 feet in length.

The quartz differs in different positions, both in the degree to which it has been subjected to dynamical forces, and in the modifications it has undergone by chemical action. Those sheets which lie either in contact with, or in close proximity to, the west wall are of a larger crystalline texture and more sparry luster, and have a greater tendency to crystallize round open vugs, and a generally harder character than those bodies which accompany the ore-channel. These differences, together with the frequent occurrence of included angular fragments of country-rock, chiefly mark the upper levels of the west portions of the lode. As the west bodies descend they approach more and more those of the ore-channel, and from their close proximity have shared the same conditions, so that toward the bottom of the wedge-like expansion of the

lode, the east and west bodies are very nearly alike. The sheets connected with the ore-channel are far more finely crushed than the western bodies, are rarely reddened to a considerable depth, and, even in their finer mineralogical features, preserve throughout the entire length of the lode a remarkable uniformity.

The quartz is of a milky-white tint, of a somewhat pearly luster, and of unusually compact, fine-grained texture. From the surface to the deepest levels these bodies have been more or less disintegrated. The crushing force has in places reduced them to a powder, equal in fineness to commercial salt, and it is rarely ever the case that the fragments exceed a foot in diameter, while those of the west vein, especially where they approach the surface, are in the form of large angular blocks, in some instances solid for a hundred feet together. Prominent instances of the solid west masses are the Eldorado outcrop of the Gould and Curry, and the Virginia vein, situated in the Ophir group. This latter has a thickness of a hundred feet and a longitudinal extent of over a thousand feet of compact, solid rock. In Gold Hill both divisions, since they belong equally to the ore-channel, are crushed very nearly alike, yet the same tendency to finer powdering is observable in the eastern body. Beside this general structure, characterizing all, each vein has within its limits more or less changes. The common arrangement is in zones, which continue throughout the entire length of the sheet. Nearly all the great ore-bearing bodies are in the form of parallel layers of crushed quartz, rarely ever separated from each other by any strong line of demarcation, but still so characteristically defined as to be traceable by the eye. A prominent example of this zonal arrangement has already been given in the notes on the Belcher mine. Here is, in fact, a single body of quartz, 61 feet in thickness, composed of five layers, which, both physically and mineralogically, differ from each other. Not only are the sizes of the fragments different in different zones, but the deposition of ore has been confined to one. Another is tinted smoke-color by minute quantities of silicate of iron; a third is a mere seam of quartz pebbles; a fourth is composed of large, irregular blocks; a fifth, an almost equal mixture of clay fragments and bits of propylite country-rock. Another interesting example occurred in the great ore-bearing chamber of the Gould and Curry. Here the easternmost zone of the body was highly

crushed, very richly charged with silver ores, and very easy to mine. After this had been stoped out for a considerable extent, it was found that the next zone, which lay in immediate contact with it, was composed of large blocks showing no ore upon their outside, but extremely rich in the interior. These fragments, often weighing half a ton, showed not the slightest trace of silver minerals for the first two or three inches from the surface, but the entire middle was one densely-charged mass of rich ore. Lying west of this again was a third and less valuable zone, which, during the earlier years, was left untouched, but which, in the later condition of labor, and the increasing scarcity of ore-deposits, was again looked into, and proved to be a valuable addition to the stoping ground.

The eastern face of the ore-channel quartz is always more or less intermingled with clay. Fragments of quartz may be found embedded a foot deep in the east clay, and masses of clay at an equal distance within the quartz. It is interesting to observe that with all this well-marked longitudinal arrangement there is not the slightest trace of the ordinary comb-structure so characteristic of many fissure veins. It is almost never the case that the zones group themselves in pairs, with the same relations to the opposite walls, which may be seen in the Freiberg veins.

A careful examination of these bodies induces the belief that the fissures were all filled at one time with uniform masses of quartz, and that the parallel arrangement has been afterward given them by the combined chemical and dynamical action to which they have been exposed. There is not a particle of evidence that the quartz and ore were successively deposited in layers upon the fissure walls from lateral secretion *in situ.* The quantitative relations of the quartz to the surrounding horse and wall-material, together with the analyses which are given further on in this section, preclude any such idea. It is evident that the fissures were filled with quartz from some deep-seated source, and that the masses when formed have been afterward subjected to dynamical action sufficient to crush them into minute fragments, without in any case faulting them. The writer believes that to the disturbance which gave vent to the andesite eruptions must be attributed the origin of the Comstock lode, and, in consequence, we have ample subsequent movement to account for any interior dislocation and dynamical action that has been

observed. The epochs of trachytic and basaltic eruption are in themselves quite enough to account for the movements which have crushed the Comstock quartz-bodies. To open a fissure of sufficient width to permit the immense volumes of trachyte-lava, which lie east of the vein, to outflow, would probably communicate sufficient pressure to the Comstock itself to produce all the effects of fracture and grinding which are shown by the fragmentary condition of the quartz, and the manner in which the east wall-material is crowded in among those fragments. The fact that the quartz is arranged in zones, which are parallel to the direction of the lode, and that the main fissure-lines traversing the horses are also parallel, shows a coincidence of direction in all the disturbing forces of the neighborhood. Such movements will indeed only account for the degrees of fineness into which the various zones of a given body are crushed. For the varied conditions of color and mineralization we must look to the varieties of chemical activity which subsequently occupied the vein. Quartz forms the only ore-gangue in the whole Comstock.

Minerals.—The catalogue of Comstock minerals, both those which combine to form the silver bonanzas, and those unimportant accompanying species, is remarkably meager. Those of value are native gold, native silver, argentite, (silver glance) polybasite, and stephanite, with some very rich galena and occasional specimens of pyrargyrite. Besides these, occur in the quartz, iron pyrites, copper pyrites, oxide of iron, manganese, sulphates of lime and magnesia, and carbonates of magnesia, lime, lead, and copper. The line of oxidation, or rather of those minerals in the form of oxides, is confined to the upper 500 feet of the lode. Here a large proportion of the iron pyrites, and all of the carbonates of lead and manganese, are changed into the oxides of those metals which produce the prevailing red hue. A zone of manganese oxide occupies the entire length of the lode from the outcrop 200 feet down. Below this, there is only a very small percentage of manganese, which is found in two forms, as the carbonates on the second level of the Savage, and in the general mass of the silver ore, probably as a part of the polybasite. It is difficult to assign the true lower limits of the "Colorado" or "Iron Hat." The quartz is reddened and the iron minerals more or less oxidized to a depth of 500 feet, but it is probable that the lower 100 feet are chiefly colored by the percolation

of surface waters. Just beneath the line of the "Colorado" is, at several points, a marked tendency to form concentric masses. This is especially the case in the Savage, where the quartz seems to have remained in a viscous condition, and to have been deposited again and again, long after the rest of the bodies had become solidified.

Bonanzas and Ore.—The special arrangement of bonanzas throughout the lode has already been made familiar to the reader by describing the various sections in detail. It remains now to make a general re-survey of the ore-bodies. In conformity with the general chimney-openings of the lode, they group themselves in three well-marked families; those of Gold Hill, Virginia, and Ophir. The three together have produced the immense aggregate of $100,000,000. Of this total, the Ophir group has produced about $7,500,000, and at the present writing the Gold Hill and Virginia groups are nearly equal. It is probable that the Virginia group has produced about $48,000,000, while the Gold Hill cannot rise greatly above $42,000,000. Within a year or two the difference will probably be turned in favor of Gold Hill. Further on, in a detailed account of production in the chapters by Mr. Hague, will be found an analyzed statement of the total product of the principal mining companies. The figures stated will include such returns as are authenticated beyond a doubt, and such as bear the official stamp of accuracy. Beside the actual bonanza account of each company, considerable sums have leaked out in the form of mill cleanings and battery scrapings. To reach the total, several millions have to be added to the official returns.

In the brief space of nine years the Comstock lode has furnished at the rate of nearly $11,000,000 per annum. This entire sum has come from the limited areas of the bonanzas. It is only in the latest periods, generally since 1868, that the extra-bonanza ore has been touched.

Turning now to Atlas-Plates 6 and 7, the reader will perceive that not more than twenty-five per cent. of the actual face of the lode has been occupied by argentiferous bodies. In the general sum of vein-material, of course, they have constituted a still smaller percentage. It is safe to say that not more than $\frac{1}{500}$ of the lode-materials have been charged with silver to a workable percentage. The upper 600 feet has furnished seven-tenths of the entire silver product. Plate 6 shows the Gold Hill bonanzas. The group

of six small stopes in the Overman are so closely arranged, and the intervals between them so nearly up to the working tenure of silver, that they may be safely called one bonanza. The Belcher and Crown Point west, and the thin sheet which traverses the Gold Hill quartz, belong, as has been seen, to the west sheet. The others occupy the east vein and arrange themselves on a middle zone along the east wall, with their greatest developments tangent to its conchoidal curve. This family of bonanzas expands from a central point in the bottom of the Yellow Jacket south mine, and distributes its bodies in a fan-shape through the quartz. Those bonanzas which rise to the south are less richly charged, smaller in area, thinner, and less definitely bounded than the northern bodies. These latter, especially the immense Gold Hill bonanzas, are very thick, very richly charged, and bounded by a sudden change in the quality of the quartz, and a sudden giving out of the tenure of the ore. It is interesting to observe that all the lines of motion which are traceable, either in the fluting of the east wall or in the striations upon clay surfaces, indicate a movement in the direction of the north bodies; and further, wherever a second deposit of quartz has been formed, it has evidently followed the general axis of the northern bonanzas, ascending from the bottom of the Yellow Jacket toward the northern Gold Hill claims, at an angle of 45°. These secondary deposits of quartz are visible in the filmy coatings of silica deposited upon the southern and lower sides of quartz blocks, and especially of quartz crystals. Wherever the gangue has formed vugs, or considerable masses of crystals, they are coated on their lower and southern sides with a crystalline deposit of silica. The largest single bonanza in the whole lode is that of Gold Hill. Its longer axis is horizontal, occupying the eastern quartz for a longitudinal expansion of 1,100 feet, descending from the surface to the 700-foot level. The Virginia chimney next north of this contains almost an exact repetition of this arrangement of bonanzas. When Baron Richthofen wrote his admirable paper on the Comstock lode, he gave it as his opinion that the mode of occurrence of ore differed in these two chambers; that while the quartz of Virginia gathered its ore in segregated bodies, that of Gold Hill contained it uniformly distributed in sheets of great length. But subsequent developments have demonstrated the incorrectness of this idea. The great Gold Hill bonanza, which gave rise to this hypothesis,

suddenly terminated on the south and gave out in depth, proving itself to be a typical bonanza, and not by any means a sheet of indefinite continuance.

From the central point of the Virginia chamber, occupied by the Hale and Norcross and South Savage, there rises a diverging series of bonanzas, arranging themselves in the same fan-like form, and reproducing, in most remarkable parallelism, the main features of the Gold Hill group. To the south are three bodies lying successively higher and further west. Of these the most southern was of the least value, while they constantly increased in size and in tenure of silver in proportion as they approached the point of divergence.

As the bonanzas rise to the north they lap one upon another, forming almost a continuous ore-body from the bottom of the Savage to the outcropping of the Gould and Curry. From this northern half of the fan has been mined in the neighborhood of $26,000,000. From the Gould and Curry claim alone, which occupies, as will be seen, only the upper 400 feet of the system, were taken $15,000,000. As in the case of the Gold Hill, nearly two-thirds of the wealth of the chamber has been derived from the northern half of the bonanza group. And here again all the structural evidences of the lode point to the fact that the most powerful currents were thrown in that direction. Not only have strong chemical currents followed the northern rise, but, subsequently to the deposition of the ore, the greater dynamical effects have also been concentrated in the northern half.

The third chamber in the lode begins properly in the north part of the Gould and Curry claim, extending from that point to the North Ophir. Those bonanzas which occupied its southern portion, in the Consolidated and California mines, were characterized by a small percentage of silver and a very unusually large proportion of base metals, prominent among which were galena, blende, and copper pyrites. The Ophir-Mexican body is the only true silver bonanza in this group, and, singularly enough, it occupies a totally different quartz body from the base metal group. The latter is found in the red quartz, which, in the Ophir, was seen to separate two propylite horses, while the former is inclosed in the white ore-channel quartz, occupying its normal position near the east wall. The bonanza itself seems to be a miniature development of the fan-like system. Its general form is a triangle with

one point turned downward, and throughout its whole extent barren portions interrupted the continuity of the silver ore, very much as the non-metal-bearing quartz lay between the bonanzas of the fan systems. The product of this body, $7,500,000, was mined at an immense profit, owing to the extreme concentration of rich ores and their nearness to the surface. The back, or eastern, ore-body was never over six feet thick, and overlapped to the north its larger neighbor. Repeating again the law of the other groups, the richest portions were at the north and near the surface.

Quartz forms the only gangue in the Comstock lode. Those small masses of carbonate of lime which occur, intermingled with quartz, in the Gold Hill and Hale and Norcross lower levels, are rather to be considered an included mineral of accidental occurrence than as a true gangue. With the exception of small quantities of silver minerals contained in the clay sheets, where they are placed in close contact with the bonanza, the whole silver-tenure of the lode is contained in the bodies of quartz. The ore itself is composed of native gold, native silver, silver glance, stephanite, polybasite, rich galena, occasional pyrargyrite, horn silver, and, with extreme rarity, sternbergite. Intimately associated with these, occur iron and copper pyrites and zinc blende. Of these, pyrargyrite and horn silver are rarities; polybasite and sternbergite, in recognizable crystals, occupy a few scattered localities; stephanite, in defined crystallizations, has been found in nearly every bonanza, but the main body of the ore is a confused semi-crystallized association of native gold and silver, vitreous silver ore, rich galena, copper and iron pyrites, and zinc blende. The following two analyses, made at the Sheffield Chemical Laboratory of Yale College, are by Mr. W. G. Mixter, an assistant of that establishment, and Mr. Arnold Hague of this corps. They are of samples from the Savage and Kentuck lower workings of 1869:

*Analyses of Comstock Ores.*

| | Savage. | Kentuck. |
|---|---|---|
| Silica | 83.95 | 91.49 |
| Protoxide of iron | 1.95 | .83 |
| Alumina | 1.25 | 1.13 |
| Protoxide of manganese | .64 | |
| Magnesia | 2.82 | 1.37 |
| Lime | .85 | 1.42 |
| Sulphide of zinc | 1.75 | .13 |
| Sulphide of copper | .30 | .41 |
| Sulphide of lead | .36 | .02 |
| Sulphide of silver | 1.08 | .12 |
| Gold | .02 | .0017 |
| Bisulphide of iron | 1.80 | .92 |
| Potassa and soda | 1.28 | 1.05 |
| Water | 2.33 | .59 |
| | 100.38 | 99.48 |
| | W. G. Mixter. | A. Hague. |

The following five analyses are from the report of R. H. Stretch, State Mineralogist of Nevada. Although less completely carried out than the others, they are interesting, since all the specimens were taken from levels which represent middle depths.

*Table of Analyses of Comstock Ores.*

| | California Mine. | California Mine. | Ophir Mine. | Yellow Jacket Mine. | Yellow Jacket Mine. |
|---|---|---|---|---|---|
| Silica | 67.5 | 65.783 | 63.38 | 98.310 | 96.560 |
| Sulphur | 8.75 | 11.35 | 7.919 | .693 | .160 |
| Copper | 1.30 | 1.31 | 1.596 | | |
| Iron | 2.25 | 2.28 | 5.463 | .575 | 2.800 |
| Silver | 1.75 | 1.76 | 2.786 | .150 | .050 |
| Gold | .059 | .57 | .059 | .005 | .001 |
| Zinc | 12.85 | 11.307 | 14.455 | | |
| Lead | 5.75 | 6.145 | 4.151 | | |
| Antimony | | | .087 | | |
| Loss | .25 | | | .267 | .429 |
| | 100.00 | 100.00 | 99.896 | 100.00 | 100.00 |
| | London. | Swansea. | G. Attwood. | W. F. Rickard. | W. F. Rickard. |

In general the ore within the limits of bonanzas is pretty uniformly disseminated through the quartz. It is only rarely that large, solid accumulations occur. The silver minerals ordinarily lie in masses about the size of a hen's egg. In the central portions of bonanzas there is usually a somewhat denser arrangement of ore; and, in their relations to the bonanza systems, the northern halves of the two groups are the richer, and the charging is more and more dense toward the surface. It is evident, from the manner in which the ore itself is broken and dislocated, that the dynamical action which powdered the quartz occurred after it was charged with ore.

There is every reason to suppose, from the manner in which the ore minerals intersect the quartz, that they were deposited while the latter was still plastic. Since the period of crushing, additional charges of quartz and ore have been introduced into the fissure to a small extent. In a few cases, as in the 800-foot level of the Yellow Jacket mine, broken fragments of quartz, themselves containing ore, have been re-cemented by sheets of stephanite which have penetrated the cracks, and over the stephanite a secondary growth of quartz crystals has taken place, and these quartz crystals themselves are again coated with a fine varnish of silica. The carbonate of lime which is found in the lower works of Gold Hill and Hale and Norcross, but more especially in the former, has crystallized in the cavities of the quartz, and in some instances has been subsequently coated with a film of quartz and then dissolved out, leaving skeleton crystals built up of thin films of silica. In the Middle Savage mine, in the region of the second station, for a considerable time quartz and ore alternated in deposition. There is a limited region where the ore and quartz form alternate concentric layers. Outside of the most recent layer of ore, in rare instances, has been formed a plating, about half an inch thick, of carbonate of manganese, which in its turn was again covered with a thin layer of silica.

The ores of Gold Hill and Virginia are very similar in their mode of arrangement and general mineralogical composition. Stephanite occurs much more sparingly in the Virginia mines than in Gold Hill. In all the ore that has been worked the average proportion of gold remains very nearly the same. In the uppermost works of the Belcher, in the upper levels of the Gold Hill group, and in the very highest portions of the Gould and Curry

bonanza, there was perhaps a slight increase over the present proportionate yield of gold. In a part of the Bullion, however, and in the Virginia vein back of the Ophir, and in the Sacramento, gold largely predominates. The metal produced from these mines averages nine dollars to the ounce. With these unimportant exceptions, the average proportion of gold is about thirty per cent. of the whole value. Eight-tenths of all the bonanzas have occurred in the ore-channel, or in fissures joining it and belonging to its system. Within this zone there has been a general tendency to accumulate where the convex face of the east wall invades the lode, as at Gold Hill, Gould and Curry, and the Ophir. The chief developments have been within 600 feet of the surface. The mineralogical characters of the ore vary very little from the surface to the lowest depths, except that above 400 feet the "Colorados" have reddened the veins, and oxide of iron in a measure replaces the sulphide of that metal.

Accidental minerals are horn silver, which in rare small crystals occurred in the outcrop of the Gold Hill group; and native copper, the latter in connection with native gold and silver; and green carbonate of copper, in an earthy, clay-like mass, occurred in the upper works of the Gould and Curry. Native copper also, in minute but well defined crystals, is found in the clays of the Sierra Nevada. This is interesting, since directly above it in the earlier works an unusual predominance of copper pyrites was found. At a depth of about 500 to 700 feet, in various parts of the lode, the ore not unfrequently assumes a greenish hue, given it by an admixture of chlorite. On the 325-foot level of the Chollar-Potosi, north of the Potosi shaft, this first made its appearance. It has occurred largely in the Hale and Norcross, and now in the 900-foot level of the Yellow Jacket is quite frequent. Together with the chlorite is chloride of silver in thin scales. Perhaps the greatest variety of unusual forms of the ore was found in the Ophir. In the back-stope of that mine, in the midst of a very rich deposit, occurred considerable masses of antimonial ore, and a singular association of rich galena and native silver. Near the lower limits of the front body were unusual accumulations of zinc-blende, which in depth associated itself more and more with galena and copper pyrites, and finally gave out at the bottom of the bonanza, the quartz there being stained with carbonates and a sulphate of copper, and the waters

charged with sulphates of copper and magnesia. Pyromorphite also occurred in the Middle Ophir. The powdered eastern quartz-mass was often held together by thick accumulations of ore, which were traversed in every direction by wires of native silver; especially was this the case in the upper levels of the Mexican. The arrangement of the minerals in the north part of the Ophir bonanza was very interesting. From the surface down to 60 feet below the Walsh tunnel, the galena, copper, and iron pyrites, with a little blende, predominated. From that point down to the great curve of the east wall, rich masses of the ordinary Comstock silver ore gave an immense value to the quartz. Thence to the bottom iron pyrites and blende gradually replaced the silver ore. In the Ophir bonanzas, more malleable sulphide of silver occurred than anywhere else in the Comstock. It is held to be an earlier product than the brittle minerals, and often performed the duty of holding together the fractured quartz. The red quartz body back of the first Ophir horse contained very little within the Ophir claim; but on the south, where it entered the California, was charged with a large body of base ores. Beginning at the 150-foot level, it extended down nearly to the Latrobe tunnel, and in a longitudinal direction stretched from the north line of the California claim 150 feet south; its general thickness was 60 feet. This body never averaged over $10 to $12 per ton, and was made up of blende, iron pyrites, and galena, the total value of silver being contained in the latter mineral.

From the position of the clay-veins, and the manner in which they not not only separate the quartz from the walls and horses, but in which they surround even the bottom of the sheets, it is evident that they were formed subsequently to the quartz periods. This is further shown by the fact that they contained rolled pebbles of quartz; yet it is singular that none of these pebbles ever carry an appreciable quantity of silver ore. The clays are undoubtedly formed by the decomposition of the propylite material, and it is only natural that where they form a contact with the bonanza that the clay itself should be more or less charged with ore. Wherever examined in the immediate neighborhood of these bodies, it has been found to be charged with silver, from a trace up to a considerable percentage. At one place in the Gould and Curry the clay yielded $5 99 of silver to the ton. Near the Potosi strike in the Savage, it is found to carry $8 10 to the

ton; and upon the east face of the Gold Hill body, at a point near the great curve of the east wall, it gave $6 50 to the ton.

TEMPERATURE OF LODE.—Throughout the interior of the lode a temperature considerably higher than that of the open air is maintained. The following table is a record of a great number of underground observations, from the Northern Gould and Curry to the South Crown Point:

*Table showing Temperatures in the interior of the Comstock Lode.*

| Mine. | Locality. | Temperature. Rock. | Temperature. Water. | Temperature. Air. | Remarks. |
|---|---|---|---|---|---|
| | | ° | ° | ° | |
| Ophir - - - - | Bottom new shaft - - - | 60 | 65 | 59 | Water dripping. Shaft 200 feet deep. |
| Savage - - - | Curtis shaft, 2d station, 180 feet from shaft. | 72 | - | 73 | |
| | Do. 3d station, north mine, 13th floor above track. | 64 | - | 64 | Barren quartz. |
| | Do - - - - - - - | 72 | | | |
| | Do - - - - - - - | 67 | - | 68 | Clay beside quartz. |
| | Do. 4th station - - | 80 | 80 | 80 | Bottom Potosi strike. |
| | Do - - - - - - - | 80 | - | 81 | Switch, north drift. |
| | Do - - - - - - - | 76 | - | - | Wet clay, 100 feet from switch. South Mine. |
| | Do - - - - - - - | 81 | - | 80 | 4th floor above track. Quartz. |
| | Do - - - - - - - | 80 | - | - | 6th floor South Mine. Quartz. |
| | Do - - - - - - - | 81 | - | - | South Mine, south drift, 4th station. Quartz. |
| | Do - - - - - - - | - | - | 77 | First switch from shaft, 4th station. |
| | Do - - - - - - - | 74 | - | - | 80 feet west from shaft. |
| | Do. 5th station - - | 85 | - | 84 | End north drift. |
| | Do - - - - - - - | 88 | - | 88 | End south drift. Little water. |
| | Do - - - - - - - | - | 83 | - | 75 feet from end drift; dripping. |
| | Do - - - - - - - | 79 | - | 78 | West drift, 50 feet from shaft. |
| | Do. bottom shaft - - | - | - | - | 45 feet below 5th station. |
| Gould and Curry | Bonner shaft, 2d station - | 69 | - | - | 100 feet west of shaft; damp. |
| | Do - - - - - - - | 75 | - | - | East clay-seam; 2 feet wide. |
| | Do - - - - - - - | 73 | - | 73 | 200 feet west of shaft. |
| | Do - - - - - - - | 79 | - | - | In east wall, 300 feet west from shaft. |
| | D-Street level, middle tunnel | 67 | - | 67 | 500 feet from shaft; 1 foot wide. |

*Table showing Temperatures in the interior of the Comstock Lode*—Continued.

| Mine. | Locality. | Temperature. Rock. | Temperature. Water. | Temperature. Air. | Remarks. |
|---|---|---|---|---|---|
| | | ° | ° | ° | |
| Gould and Curry | Six floors above middle tunnel. | 79 | - | 78 | Old shaft; old works being reworked, but specimen never disturbed. |
| Hale and Norcross. | Fair shaft, 72 feet above 2d station. | 87 | - | 89 | South end drift on east wall; quartz 4 inches thick. |
| | Do - - - - - - - | 86 | - | 89 | 95 feet south of west winze. |
| | Do - - - - - - - | 83 | - | 86 | End west drift, northwest winze; slight leakage water; mixture quartz, syenite, and clay. |
| | Do - - - - - - - | 84 | - | - | Southwest end; wall between ore and east wall 65 feet north of west winze. |
| | Do - - - - - - - | 84 | - | - | On east wall; some fragments of quartz. |
| | Do - - - - - - - | 82 | - | 83 | Quartz about 6 inches thick. |
| | Do - - - - - - - | 82 | | | |
| | 930 level, north drift - - | 83 | - | - | Quartz 6 inches thick. |
| | Do - - - - - - - | 84 | - | 84 | Horse. |
| | Do - - - - - - - | 73 | - | - | 260 feet from shaft, east wall. |
| | Do - - - - - - - | 72 | - | 73 | Clay 3 feet thick. |
| | Bottom of winze at west switch. | 82 | - | - | 25 feet deep. |
| | Do - - - - - - - | - | 84 | 80 | Water dripping. |
| | 930 level, north drift - - | - | - | 84 | 80 feet from shaft. |
| | Bottom of shaft, 850 feet - | 73 | 75 | 70 | Water east side. |
| Chollar Potosi - | Chollar-Potosi shaft - - - | 83 | - | 85 | Mouth of shaft; west wall 1,000 feet below. |
| | 3d Santa Fé, south drift - | 73 | - | 74 | 800 feet from Potosi shaft. |
| | Do. 70 feet North Potosi shaft | - | 73 | - | In wall, water dripping. |
| | Belvidere side-drift, end - | 60 | - | 64 | Water oozing. |
| Yellow Jacket - | New shaft, 733-foot level - | 88 | - | 86 | In east wall, east from shaft. |
| | Do - - - - - - - | 86 | - | 81 | Running south in vein. |
| | Do - - - - - - - | 78 | - | - | Below Yellow Jacket winze. |
| | Bottom of shaft - - - - | - | 92 | | |
| | Do - - - - - - - | 81 | - | 76 | |
| | New shaft, 550-foot level - | - | 80 | 70 | Bottom first chute, west drift. |
| | Do. - - - - - - - | - | - | 76 | |
| | Do - - - - - - - | - | - | - | Horse of porphyry, 60 feet from south end of claim. |
| | New shaft, 570 level - - - | 76 | - | 73 | Bottom second winze; stope. |

*Table showing Temperatures in the interior of the Comstock Lode*—Continued.

| Mine. | Locality. | Temperature. Rock. | Temperature. Water. | Temperature. Air. | Remarks. |
|---|---|---|---|---|---|
| | | ° | ° | ° | |
| Yellow Jacket | New shaft, 570 level | 77 | - | - | Clay 1 foot wide, running with vein 2 feet wide. |
| | Do. 550-foot level | 75 | - | - | In vein, 100 feet south of shaft; east wall. |
| | Do. 450-foot level | 72 | - | - | West drift, 350 feet from shaft. |
| | Do | 61 | - | 63 | 20 feet from shaft. |
| Imperial and Empire. | New shaft | - | 93 | - | Tank at top of shaft. |
| | Do | - | 96 | 97 | From bottom. |

The Ophir works being inaccessible at the time of this study, we have no very definite ideas relating to the thermal conditions of that part of the lode; but such a uniformity exists in the relations of temperature and depth that it cannot be doubted that the Ophir would repeat the conditions observed so uniformly elsewhere. The vein-material is all wet with infiltrated waters, which may be classed in two systems: those which owe their origin to surface drainage, and percolate downward from the outcrop of the lode; and those which rise from great depths, arriving at the lower mine-works in a more or less heated condition. The former are dammed up by the various clay-seams, penetrating to greater or less depths according as the clays pinch out or continue deeply downward; the upper portion of the lode, especially that which has expanded in the V-form, is a continuous series of water chambers. As mining developments have progressed, these chambers, one after another, have been drained and pumped out. Within the main portion of the lode, subterranean galleries tapped successively nearly all these water bodies, and there are no longer any great isolated collections; but the constant influx necessitates a very elaborate system of pumping machinery, as will hereafter be seen from Mr. Hague's chapter. By referring to the table, the reader will see that the average temperature of these waters, from the surface to 700 feet downward, is about 70° to 75° Fahrenheit; while those which are found in the lowest workings of the Empire, Crown Point, and Hale and Norcross, rise to a maximum of

108° Fahrenheit. The vapors from these hot waters fill the lower chambers of those mines, penetrating every crevice and fissure-line of the vein-material, and have converted the whole lower zone into a moist, steaming region. An interesting instance of the heated waters occurred in the North Ophir mine. When drifting west from the Palmer shaft, a body of clay was cut, and immediately after penetrating it there poured in such volumes of heated water that the miners were barely able to jump upon the cage and escape to the surface; the water rapidly following them filled the shaft over 100 feet deep. The temperature of this hot water irruption is said to have been 104°. That to the waters is due the temperature of the whole interior of the lode is evident from the fact that they average a few degrees higher than the clays or rocky material.

CHEMISTRY OF VEIN MATERIALS.—Below is given the result of chemical examinations of mine waters from various localities.

*Analysis of water from the* 600-*foot level of the Savage mine, by Professor S. W. Johnson, of Yale College.*

One liter contained

| | Grammes. |
|---|---|
| Silica | .0305 |
| Alumina and Ferric oxide | .0009 |
| Chloride of Sodium | .0021 |
| Sulphate of Lime | .5044 |
| Sulphate of Magnesia | .0308 |
| Carbonate of Potassa | .0148 |
| Carbonate of Soda | .1297 |
| Carbonate of Magnesia | .0512 |
| | .7644 |

*Table showing Qualitative Determination of Comstock Mine Waters, by Eugene S. Bristol.*

| | Yellow Jacket, bottom of new shaft. | Yellow Jacket, west drift, 500-foot level. | Empire-Imperial, bottom of new shaft. | Hale and Norcross, bottom of new shaft. | Hale and Norcross west drift, 930-foot level. | Savage, fifth station, north drift. | Ophir, bottom of new shaft. |
|---|---|---|---|---|---|---|---|
| Solid contents, grammes* | 0.0553 | 0.3271 | 0.0615 | 0.0924 | 0.0784 | 0.2660 | 0.080 |
| Bases - - - - - - | Lime. | Lime. | Lime. | Lime. | Lime. | Lime. | Lime. |
| | Magnesia. | Magnesia. | Magnesia. | Magnesia. | Magnesia. | Magnesia. | Magnesia. |
| | | | Potassa. | | | Potassa. | |
| | Soda. | Soda. | Soda. | Soda. | Soda. | Soda. | Soda. |
| | | | Alumina. | | | | |
| Acids - - - - - - | Carbonic. | Carbonic. | | Carbonic. | Carbonic. | Carbonic. | Carbonic. |
| | Sulphuric. | Sulphuric. | Sulphuric. | Sulphuric. | Sulphuric. | Sulphuric. | Sulphuric. |
| | Phosphoric. | Phosphoric. | Chlorine. | | Phosphoric. | Phosphoric. | Chlorine. |
| | | | Silicic. | Silicic. (Trace.) | | | |

*In 100 cubic centimeters of water.

A considerable series of less extended analyses is given above. In these the amount of solid matter per 100 cubic centimeters is first given, then a qualitative enumeration of contents. It will be seen that beside the elements found in the Savage water, that from the Yellow Jacket shaft contains phosphoric acid, which also occurs in the lower Hale and Norcross and in the fifth station of the Savage. The contents of these waters, together with their temperatures, illustrate nearly all the chemical agents now actively engaged in the vein. Below are given three tables: one of analyses of the clays; another of horse materials; a third contains the prominent rocks of the neighborhood, propylite and andesite.

*Table of Quantitative Analyses of Comstock Clays.*

| | Yellow Jacket. East clay. | Chollar. West clay. | Hale and Nor-cross. East clay. | Savage. Second Station. |
|---|---|---|---|---|
| Silica - - - - - - | 60.02 | 59.71 | 65.69 | 39.52 |
| Phosphoric acid - - | .34 | Trace. | Trace. | Trace. |
| Carbonic acid - - | 3.17 | | | 6.20 |
| Alumina - - - - - | 12.15 | 17.59 | 15.39 | 15.97 |
| Ferric oxide - - - | 4.38 | 5.04 | 2.11 | 4.47 |
| Lime - - - - - - | 6. | .73 | 1.66 | 9.20 |
| Magnesia - - - - - | 1.40 | 4.41 | 2.85 | 3.40 |
| Potassa - - - - - | 1.23 | 3.98 | 4.64 | 3.11 |
| Soda - - - - - - | .45 | 1.01 | 2.36 | |
| Water - - - - - - | 8.09 | 4.19 | 2.80 | 9.95 |
| Pyrites - - - - - - | 1.84 | 3.58 | 2.84 | 9.18 |
| | 99.07 | 100.24 | 100.34 | 101.00 |
| | Prof. S.W. Johnson. | W. G. Mixter. | W. G. Mixter. | Prof. S.W. Johnson. |

*Analysis of Propylite Horse, by W. G. Mixter.*

| | Yellow Jacket. 830-foot level. |
|---|---|
| Silica - - - - - - - - | 80.27 |
| Alumina - - - - - - - | 9.39 |
| Ferric oxide - - - - - | 2.17 |
| Manganous oxide - - - | Trace. |
| Magnesia - - - - - - - | Trace. |
| Lime - - - - - - - - | 0.54 |
| Potassa - - - - - - - | 2.19 |
| Soda - - - - - - - - | 1.94 |
| Water - - - - - - - - | 1.83 |
| Pyrites - - - - - - - - | 1.69 |
| | 100.02 |

*Table of Quantitative Analyses of Rocks, by W. G. Mixter.*

| | Andesite. | Propylite. |
|---|---|---|
| Silica | 59.22 | 58.68 |
| Alumina | 18.20 | 17.90 |
| Ferric oxide | 6.69 | 4.11 |
| Lime | 5.51 | 5.87 |
| Magnesia | 2.90 | 2.03 |
| Potassa | 1.39 | 3.19 |
| Soda | 3.31 | 2.07 |
| Water | 2.80 | 6.53 |
| | 100.02 | 100.36 |

From these chemical data it is seen that the propylite, waters, and iron pyrites, furnish all the materials for the chemical action now going on in the vein. To the orthoclase of the propylite, with its large proportion of potassa, may be traced the potash which is found so frequently in the waters and vein-materials.

The horses from various localities throughout the lode have been examined for silica and were found to contain from 68 to 85 per cent. The quantitative analysis of a propylite horse above given, represents a fair average of their chemical composition. The comparison of the tenure of silica with that of the propylite shows the important fact that all the vein-materials are more highly charged with silicic acid than is the normal propylite wall-rock. When it is considered that so basic a rock as the syenite forms the other wall, the writer thinks the conclusion inevitable that the immense masses of quartz cannot be the result of lateral secretion *in situ.* The horse materials, especially, contained rather more silica than the normal propylite, and those specimens which have been taken from the immediate east country, are charged to their normal percentage with silica. Whence then is the enormous volume of this mineral? That it came from below, brought upward by the ascending currents of hot water, there seems to be little doubt; likewise that it filled the fissured chambers with a uniform charge of quartz is evident from their internal structure. The rocks upon either side in immediate contact with the vein, and as far as we have seen in the eroded gorges of the syenite, and

for a distance of at least 600 feet to the east of the vein, contain their normal equivalents of silicic acid. But after passing the zone of 600 feet to the east of the vein, the country-rock for a mile and a half is filled with seams parallel to the Comstock lode; is fissured in every direction with a net-work of minor cracks, and has lost its original texture by solfataric decomposition. Here we find the silica contents almost gone. The greater part of this wide zone lying east of the Comstock has been reduced to a more or less ochreous, earthy rock, from which almost the last traces of silica have been taken. Supposing the Comstock to continue downward, along the inclined west wall, at no great depth, the solfatarized zone would be entered. It seems most probable that the whole mineralogical contents of the lode were sent upward from that region. In the immense withdrawal of silica from the rocks of that zone is a sufficient supply for the Comstock fissures.

Paragenesis of Materials.—The only facts beside those already cited, which throw additional light upon the origin and mode of occurrence of the Comstock, are the paragenetic relations of the various mineral materials. In a large way, of course, the horses are the earliest included materials. Next to them the fissure chambers were filled with quartz. After the quartz the percolating of waters, the attrition of rolled pebbles along their sides, and the thermal decomposition of horse and wall produced those sheets of clay which, in remarkable persistence, line every surface of quartz, and define every line of fissure. That they are later than the quartz is proven by their containing pebbles of that mineral, by their cutting it in certain instances, and by their surrounding it in every direction. The following series of minerals has been observed. The main ore-mass of the bonanzas is composed of, first, quartz; secondly, an assemblage of crystalline combinations of gold, silver, silver glance, blende, galena, and copper pyrites, the latter two ordinarily in small proportion; thirdly, unimportant, secondary introductions of quartz, which occur as coverings and casts of earlier quartz crystals; fourthly, polybasite and stephanite, which throughout the whole length of the lode occur sparingly in well defined crystals; fifthly, carbonate of lime; sixthly, a third occurrence of quartz covering the carbonate of lime, and in some instances remaining in the form of a shell, after that mineral has been entirely dissolved away. Iron pyrites

belongs to the period of the earliest formation of the silver sulphides, and seems to have continued to a very late period, certainly until after the formation of the latest clays, for there are no important seams which are not more or less impregnated with the small, brilliant crystals of this mineral. Carbonate of manganese occurs but once, and in that case occupies a position between the main introduction of sulphides and the latest quartz formation. The other carbonates, those of lead, lime, and copper, belong also to this same period. The oxides, of which there are only those of iron and manganese, are wholly superficial products, belonging to the phenomena of the "Iron Hat," and resulting without doubt from the decomposition of the carbonate of manganese and the sulphides of iron. Of the accidental rare minerals, pyromorphite, which occurred in the Ophir, belongs to the upper levels, and its relations with the other materials were never clearly understood. Horn silver was found by Küstel in the outcrops of Gold Hill, but there is no information concerning its paragenetic relations. The sulphates are wholly later than the latest introduction of quartz. They occur, first, in the form of selenite; secondly, in those soluble sulphates with which the waters of the lode are now so largely impregnated; and, thirdly, in that important zone of gypsum which occurs in the east country-rock, from a depth of from 600 to 900 feet below ground. From the Ophir to the Yellow Jacket this zone is more or less impregnated with gypsum, which occurs filling the cracks and fissures of the propylite, its fibrous crystals arranged diagonally to their surfaces. The distribution of the gypsum or selenite is one of the most interesting phenomena of the vein. At four or five places in the middle works of the lode, such as the Gould and Curry fourth, and the bottom of the Fair View shaft, were found beautiful crystals of selenite resting upon the latest quartz, later, therefore, than any of the metallic introductions, unless it be those sulphides of iron which are found in the clays. Natrolite and chabazite, with a rare association of stilbite, occurred in the black dike of the Gould and Curry, and near the bottom of the North Yellow Jacket shaft. A second growth of selenite has also recurred, its crystals resting upon those of the zeolites. The clays were probably completed before this latest introduction of quartz, since certain of their surfaces and cracks are penetrated by it. After this latest quartz the zeolites, and then the sulphates, subsequent to which we have the "Iron Hat" with its

oxides of iron and manganese. It is important to observe here that the periods of most active crushing of the quartz were prior to the introduction of the stephanite. Angular fragments of quartz, which are found imbedded in the clay, never contain that mineral, while they are often more or less charged with the silver glance ore.

Mode of Continuance in Depth.—So far the study and consideration of the lode has been confined to its past and present history. More interesting than these, by far, is its future condition and its probable mode of continuance in depth. In some respects this is the most difficult and perplexing period for an out-look which has occurred since the working of the district. During the last three years the gradual convergence of the bonanzas, both in the Gold Hill and the Virginia group, has given an unfriendly aspect to the lower region of the lode, and cast a decided shadow upon the future. In many places, as has been seen, the lode was found to terminate in a mere line of fissure scarcely marked by even a thin parting of clay. It began to be very seriously questioned by careful men whether, sooner or later, the whole of the ore-channel would not follow this unfortunate example, and close out altogether. The walls in Gold Hill decidedly converged, those in Virginia approached each other with a rapidity which bade fair, after a few hundred feet deeper, to bring them together, and it looked very much as if 500 feet at the utmost would end the productive zone of the Comstock. Against this view were the prominent facts of the immense masses of vein-material, which analysis of the various constituents proves to have been introduced from some distant source. To suppose these poured in from the surface is an hypothesis so utterly at variance with all our ideas of the past condition of the range as to be untenable even for a moment. It is considered as certain that those vein-materials which are not either portions of the country-rock that have fallen into the chasm, or such as are clearly derived from their decomposition, have been introduced from below. This indefinite source of supply most probably lies at a considerable depth beneath that portion of the east country-rock which is most thoroughly decomposed by solfataric action. It became a matter of intense interest to discover those points where the great gashes of the ore-channel should open out into the true or deep-seated fissure, and when mine after mine worked downward and

found the two walls coming into close contact, with no appearance of the re-opening of a downward chamber, the very existence of such deep-seated fissure was more than doubted. The great structural puzzle of the lode for three years has been to find the vents through which the quartz ascended and filled the fissures of the ore-channel. Within the last year a new aspect has been put upon the whole question. In Gold Hill, the west clay-seam, after steadily and uniformly approaching the east quartz to within 60 feet of actual contact with it, has now opened downward into almost exact parallelism with that body. At the lowest working in the Virginia group, at a point in the Hale and Norcross, or directly within the widest eastern expansion of the Virginia chamber, the east fissure opened more and more into an inclined position, until now, in the deepest works, the walls are approaching parallelism, and the conditions assuming more and more those of a simple fissure. In the previous pages reasons have been given which seemed to forbid the idea of the quartz being segregated by lateral secretion *in situ.* If it ascended from the depths below, as there can be no doubt it did, it must have had a very considerable channel, for its immense volumes forbid the idea of a slow seepage through a very contracted channel. It is possible for the quartz to have risen either through one general fissure, or to have found an entrance into the gashes of the ore-channel through two or three narrow chimneys. Had the former been the case it is difficult to conceive any reason for the peculiar disposition of the bonanzas. Had it been equally easy for the quartz to ascend at any part of the lode, and had the nature of the fissure given free vent to ascending currents either of water or metallic vapors, there would seem to be no reason why the bonanzas would not have been more equally distributed through the quartz. Decidedly the most remarkable feature of the silver distribution is that, with an immense surface expansion, it focuses downward in three points, at Gold Hill, Virginia, and Ophir. This is somewhat due, no doubt, to the fact that the ore-channel stands at a much greater angle than the west wall, and that the junction of these two systems of fissuring would naturally produce some barriers to the upward transit of material. It is dangerous to hazard a conjecture as to the mode of occurrence below; it is working altogether in the dark. The indications at present are insufficient to warrant any well-grounded conclusion. This, of course, offers but little

encouragement in a financial point of view; but the absence of bad prospects is in itself an encouraging feature, and there is certainly nothing in the present lowest developments of the lode which will at all warrant the belief that the metallic yield must necessarily cease. While it seems improbable, from the configuration of the ground and the relations of the fissures, that there can ever again be such a magnificent expansion of bonanzas, yet there is no strong reason why a total cessation of the silver minerals should be expected. The examples of other great veins, all that we know of the mode of deposition and chemical transmutations of silver ore, rather favor the idea of a continued silver occurrence in depth. But the lode is in many respects unique, and it may be considered as established that only actual exploration can determine the important question of the future.

Résumé.—The results of this long and perhaps tedious investigation may be summed up in the following statement of conclusions: The ancient Virginia Range, prior to the Tertiary period, was composed of sedimentary beds of the great Cordillera system, which, in the late Jurassic epoch, had been folded up, forming one of the corrugations of that immense mountain structure which covers the western front of our continent. Accompanying this upheaval were outpourings of granite and syenite. The erosion which followed this mountain period escarped the ancient rocks, and modeled the eastern front of Mount Davidson into a comparatively smooth surface, whose average angle of slope sank to the east at about 40°. In the late Tertiary, at the time of the volcanic era, the Virginia Range shared in the dynamical convulsions which gave vent to successive volcanic outflows of immense volume and very remarkable character. The first and, so far as the Comstock lode is concerned, the most important, was of propylite, or trachytic greenstone, which deluged the range from summit to base, covering large portions of its ancient surface, and leaving here and there isolated masses, which rose like islands above the wide fields of volcanic rock. Subsequently followed the period of the andesites which, at their commencement, in the form of a thin intrusive dike, penetrated a new-formed fissure on the contact plane of the ancient syenite and the propylite. This earlier andesite period gave birth to the solfataras, which, bursting from a hundred vents, rapidly decomposed the surrounding rocks, and gradually filled the fissures of the Comstock with their remarkable

charges of metal-bearing quartz. The latest flows of andesite poured out over the decomposed propylite; and since they are themselves unaltered, their appearance marks the period when solfataric action over wide areas had ceased. While it no longer maintained its energy through the broad zone of propylite, it still continued intensely active within the chambers of the Comstock lode. Metallic contents were introduced into the the quartz, the clay-seams were formed by a rapid decomposition of the neighboring propylite materials, the horses reduced to a spongy, semi-plastic condition, and at last the final solidification of the quartz took place. Outside of the vein two events of geological interest have occurred: first, the period of trachyte eruptions, when from the ruptures of the crust, parallel to the Comstock lode, vast volumes of sanidin-trachyte overflowed the country; and, secondly, the less powerful but still important outpouring of basaltic rock, which marked the close of the volcanic era. Within the vein, and probably caused by one or both of these latter volcanic disturbances, a pressure has been exerted which has crushed and ground the masses of quartz into minute fragments. It is interesting to observe that while this force was great enough to crush quartz-masses one hundred and fifty feet in breadth into mere angular pebbles, the disturbances were insufficient to cause any actual faulting of importance. Both within and without the vein the solfataras gradually came to a close. The heated currents of water which even yet ascend into the lower levels of the mines, are evidence that at no very great depth a considerable temperature is still maintained; but this is only a faint relic of a once intense action.

No chemical theory will be advanced as to the origin of the quartz, nor of those delicate questions of magneto-chemical introduction and subsequent transmutations of the metallic minerals. They belong rather to an abstruse study of the theory of veins in general than to an investigation of a particular district. The writer has endeavored to present the most important facts that came within his observation, in the hope that a patient reader may gain a general view of the structure and chemistry of this celebrated lode.

# CHAPTER III.

## THE COMSTOCK MINES.



## SECTION I.

### GENERAL METHOD OF EXPLOITATION.

It is the object of this chapter to describe the methods by which the mines of the Comstock lode are worked, and to show the general condition of mining industry in the district of which that lode is the principal feature.

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NOTE.—The writer takes occasion here to express his obligation to many gentlemen, superintendents of mines and mills in the vicinity of Virginia City, and officers of mining companies, for much assistance in obtaining the information embraced in this and the following chapter. He is especially indebted to Mr. LOUIS JANIN, Jr., formerly superintendent of the Gould and Curry Mine, Mr. CHARLES BONNER, superintendent of the Savage Mine, Mr. JAMES FAIR, superintendent of the Hale and Norcross Mine, and Mr. ISAAC L. REQUA, superintendent of the Chollar-Potosi Mine; also, to Mr. LOWELL, Mr. FRANK THAYER, Captain RAWLINGS, and Mr. JOHN O. PLATER, officers of the Savage Mining Company, and to the Hon. F. A. TRITLE.

His thanks are also due to the officers of Wells, Fargo & Company's Express, not only in Nevada but elsewhere, for many favors; and to Messrs. J. H. CARMANY & COMPANY, proprietors and publishers of the Commercial Herald and Market Review, of San Francisco, for much statistical information.

The following publications have been frequently referred to by the writer during

The Vein.—The geological features of the vein and its inclosing rocks, its general structure, and the character and method of distribution of its ore-bodies, have been so fully discussed in the foregoing chapter that, in what follows, these matters will receive only such attention as may be made necessary by their intimate connection with the branch of the subject under present consideration.

The course of the Comstock lode is nearly north and south, maintaining a general conformity in direction with the trend of the Washoe Mountains, in which it is contained. Its croppings extend in a broad, irregular belt along the eastern slope of the range, at an altitude of about 2,000 feet above the level of the plain to which the hills descend, and about 1,300 or 1,400 feet below the summit of Mount Davidson, the highest point in the range.

The western, or foot-wall, dips to the eastward from near the surface to the greatest depth attained, at an angle varying from 35° to 55°. The eastern, or hanging-wall, is ill-defined, especially in the upper portion of the lode, but at the depth of several hundred feet the two walls, or what are usually recognized as such, descend with considerable regularity, dipping easterly at about 45°.

The size of the vein is irregular, the walls being in close contact with each other at some points, and at others diverging and expanding, so as to include between them masses of vein-matter several hundred feet wide. Within these immense spaces, filled by material of varied character, are the bodies

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the preparation of these chapters, and are commended to the reader as valuable sources of information: The Reports on Mineral Resources by the United States Commissioner, Mr. J. Ross Browne, and his successor, Mr. R. W. Raymond; the Reports of the State Mineralogist of Nevada, Mr. R. H. Stretch, and his successor, Mr. A. F. White; Reports of the Surveyor General of Nevada, Mr. S. H. Marlette; and the official reports of mining companies.

The plates illustrating this volume have been prepared from notes and drawings obtained in the field during the progress of the survey; the final work of preparing them for the engraver has been done, under the supervision of the writer, by Mr. Ellsworth Daggett, of New Haven, and Mr. A. Pohlers, of Washington, to whose skill as draughtsmen, combined with a practical knowledge of the subject, they owe much of whatever merit they possess.

All money values quoted in this and following chapters, referring to the State of Nevada, are, unless otherwise stated, expressed in coin.

of ore-bearing quartz, whose peculiar features have been already described and the extraction of which is the object of the miner.

The extent to which the vein has been clearly traced, and on which mining claims have been located, is about four miles. At either extremity of this ground, however, and particularly on the north, the vein has been but little explored and has not been thus far proved to be very valuable. Its developed, and, so far, productive portions, are included within about two miles, and within these last named limits the ore-bodies have been found to occur in disconnected groups, separated from each other by long intervals of barren ground.

Mining Claims.—The following is a list of the mining claims located on the course of the lode as far as its continuity has been traced with any certainty. It gives the length of ground claimed by each company or individual owner, beginning at the north and proceeding towards the south:

*List of Mining Claims on the Comstock Lode.*[1]

| Name of company. | Length of claim in feet. | Name of company. | Length of claim in feet. |
|---|---|---|---|
| Utah | 1,000 | Bacon | 45 |
| Allen | 925 | Empire, (North mine) | 55 |
| Sierra Nevada | 1,959 | Eclipse | 30 |
| Union | 500 | Trench | 20 |
| Ophir, (North mine) | 1,200 | Empire, (South mine) | 20 |
| Mexican | 100 | Plato | 10 |
| Ophir, (South mine) | 200 | Bowers | 20 |
| Central[2] | 150 | Piute | 20 |
| California[2] | 300 | Winters and Kustel | 30 |
| Central No. 2[2] | 100 | Consolidated | 21 |
| Kinney[2] | 50 | Rice Ground | 13½ |
| White and Murphy[2] | 210 | Imperial, (South mine) | 65⅔ |
| Sides[2] | 500 | Challenge | 50 |
| Best and Belcher | 250 | Confidence | 130 |
| Gould and Curry | 1,200 | Burke and Hamilton | 40 |
| Savage | 771 | Yellow Jacket | 943 |
| Hale and Norcross | 400 | Kentuck | 93⅔ |
| Chollar-Potosi | 1,434 | Crown Point | 540 |
| Bullion | 940 | Belcher | 940 |
| Exchequer | 400 | Segregated Belcher | 160 |
| Alpha | 278½ | Overman | 1,200 |
| Apple and Bates | 31½ | North American | 2,000 |
| Imperial, (Alta) | 118 | Baltimore American | 2,000 |

[1] Report of R. H. Stretch, State Mineralogist of Nevada, 1866. [2] Virginia Consolidated.

Each claim mentioned in the foregoing table formerly represented a distinct and separate ownership in the vein, originally acquired by location under the laws of the State. A few of them have since been consolidated, reducing slightly the number of individual owners. Many of these claims are very short, their length varying from 10 to 2,000 feet. The length of each claim, as given in the table, is measured along the line of the lode, or in a nearly north and south direction, covering in width the whole of the known extent of the vein between the east and west walls. The difference of opinion regarding the position of these walls and the relation sustained toward each other by parallel bodies of ore, separated by country-rock, but all included between what are now held to be the main walls of the vein, was, in former years, a fruitful source of litigation, involving the expenditure of millions of dollars.

Each claim, with few exceptions, is represented by an incorporated company. In most cases, formerly, the number of shares in any company was equal to the number of lineal feet contained in its claim on the lode; latterly, however, nearly all the more important companies have found it desirable to increase the number of their shares, and this has been done by subdividing each foot into fractional parts, usually twelve or twenty in number.

The subdivision of the workable portions of the lode among so many independent owners, has not only given rise to much expensive litigation, but has doubtless increased the cost of development, multiplying the expenses of administration, the outlays for machinery, and other requisite equipment of the mines, and in various ways involving expenditures that would be avoided under more comprehensive or consolidated management.

All of these companies have explored their ground to some extent, and most of them throughout the entire length of their claim; but the number of those that have attained great success as producing mines is comparatively small. These latter, whose locations fortunately covered the great bonanzas, form four or five distinct groups. The northernmost comprise the claims of the Ophir and Mexican mines, from which a large amount of bullion was produced in the earlier years of the development of the lode.[1] Adjoin-

[1] The Sierra Nevada, north of the Ophir, has latterly become a successful and profitable mine. Its product, however, has thus far been chiefly gold, derived from surface rock. Its deeper explorations have not developed large bodies of silver ore.

ing these on the south is a portion of the vein that, so far, has been unproductive, amounting in extent to about 2,000 feet, at which point begins the next group of bonanzas, on which the Gould and Curry, the Savage, the Hale and Norcross, and the Chollar-Potosi are situated. Further south, separated from the last-named group by some 1,500 feet of ground, in which the Bullion claim has been explored with a wonderful persistence, and so far without any reward, is the next important and one of the most productive groups of ore-bodies yet developed. Here is a series of claims, some of them very short in extent, beginning with the Exchequer and Alpha and extending southerly to the Crown Point, covering, in the aggregate, some 2,500 feet of ground; this portion of the vein, excepting some slight intervals, has been very productive. Still further south, the Belcher and the Overman have found considerable bodies of ore, but less important than those before referred to.

General Method of Operation.—The earlier developments of the lode were made by sinking shafts upon it or by driving adit-levels through the eastern country-rock to cut the ore-bodies in depth. This latter method was employed by the Gould and Curry and served in the extraction of the greater portion of their workable ground. Other companies operated by means of shafts, and these, in early days, were sunk upon the croppings. At that time, before the structure of the vein had been discovered by actual work, the false pitch of the eastern wall and a slight westerly pitch of some of the ore-bodies, led to the belief that the vein would permanently dip to the west. As developments proceeded, however, the eastern dip of the western, or foot-wall, with the probable conformity of the eastern wall to it in depth, became clearly apparent. The shafts, sunk on the croppings on the northern part of the vein, reached the west wall at a depth of 400 or 500 feet, and penetrated the hard syenite below the vein. As the increasing depth of such shafts constantly increased the distance between the bottom of the shaft and the vein, and as the ground above, in the vein, was of a soft character and difficult to sustain, the plan of locating deep shafts at 800 or 1,000 feet east of the croppings and sinking through the eastern country-rock to strike the lode at a considerable depth, was adopted, first by the Gould and Curry, and afterward by nearly all of the principal mines in the vicinity.

Shafts of this character, designed for permanent and extensive operations, liberally planned and constructed in the most substantial manner, and furnished with the best of machinery for pumping and hoisting, are now being sunk by the Ophir, Gould and Curry, Savage, Hale and Norcross, Chollar-Potosi, and Empire-Imperial companies. The depths attained by these several shafts vary from 700 to about 1,300 or 1,400 feet. The deep mines further south, the Bullion, Yellow Jacket, Kentuck, and Crown Point, are still working through the shafts originally sunk near the croppings of the vein, but in the vicinity of the last-named mines the west wall is only encountered at a much greater depth than in the more northerly portions of the lode.

At the present day the greater part of the ore extracted from the vein is brought from a depth exceeding 500 or 600 feet, and the underground work of the leading mines is necessarily prosecuted through these deep shafts. As the sinking of these progresses, stations are established at successive distances, usually at intervals of about 100 feet, and from these stations, levels or tunnels are driven from the shaft to the vein for purposes of exploration or extraction. The ore-body being reached, it is stoped out overhand; that is, the level is driven under the body of ore to be worked out, and the ground overhead is thrown down and carried in cars from the stope to the shaft, where it is raised to the surface.

The drainage of the deep workings must, of course, be effected by means of the shafts. The adits or tunnels, driven in from the surface to the upper portion of the lode, serve to drain the ground above them, but as operations are now carried on far below their level, the accumulating water must be collected at the shaft and raised to the surface or to an adit-level. For this purpose the deep shafts are provided with pumps of adequate capacity, and the water encountered in the various parts of the mine, finding its way to the shaft, is thus discharged at the surface.

The various operations included in this work, comprising the sinking and timbering of the shafts, the construction of the drifts or tunnels, the working and timbering of the stopes, the extraction of the rock, the machinery employed for hoisting, pumping, and ventilation, and the arrangement of these works on the surface, will now be reviewed somewhat in detail.

Mine Shafts.—The deep shafts of the several leading mines on the


Fig. 1.

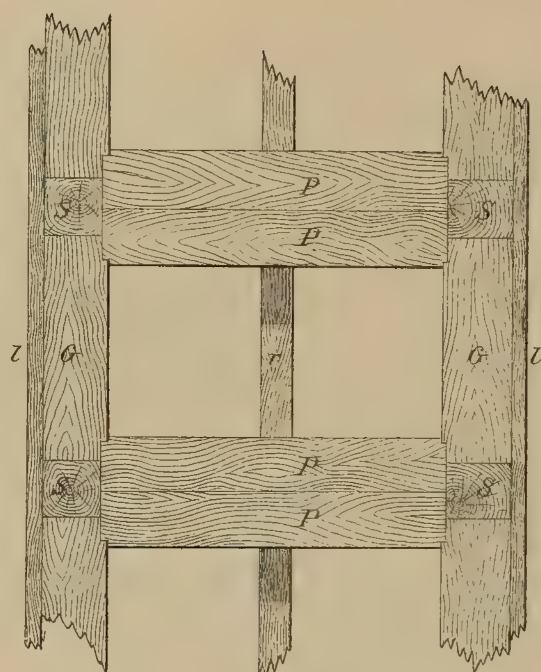



Fig. 2.

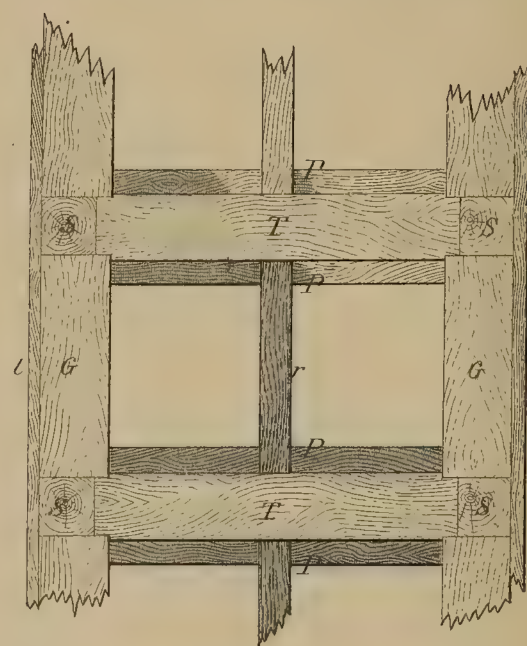



Fig. 3.

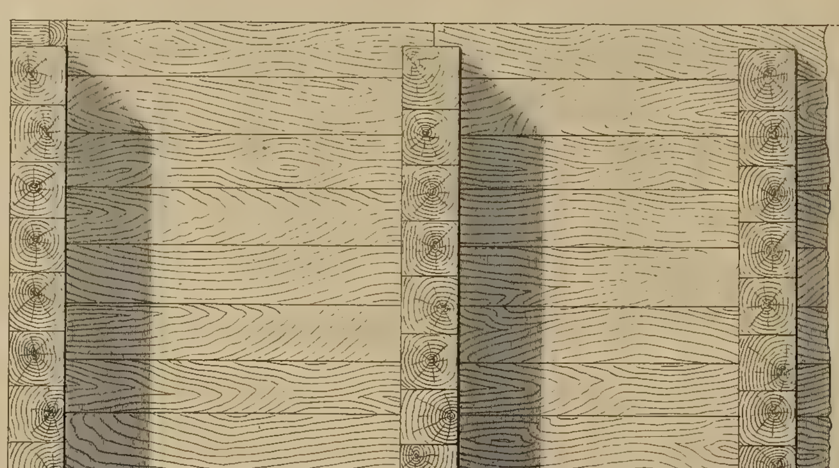


Fig. 4.

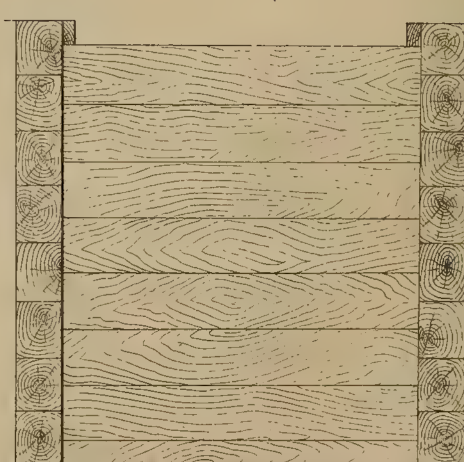


Fig. 5.

Scale: $\frac{1}{48}$.

Comstock resemble each other in general features, They are sunk vertically and, as they pass through ground of rather unstable character, require to be timbered from top to bottom. They are from $4\frac{1}{2}$ to 6 feet wide, and from 20 to 24 feet long, inside, between the timbers. They are usually divided into four compartments, one for pumping and three for hoisting. Of the latter, two compartments are usually devoted to the general work of hoisting from the mine, while the remaining one is exclusively used in the further sinking of the shaft.

The present working shaft of the Savage mine, the description of which may serve as an example of the others, is 24 feet long in the clear between the end-timbers and 6 feet wide. It has three compartments for hoisting and one for pumping. The latter is 6 feet square in the clear; the hoisting compartments are 6 feet (the width of the shaft) by 5 feet, and the three partitions between the compartments are formed of 12-inch timbers.

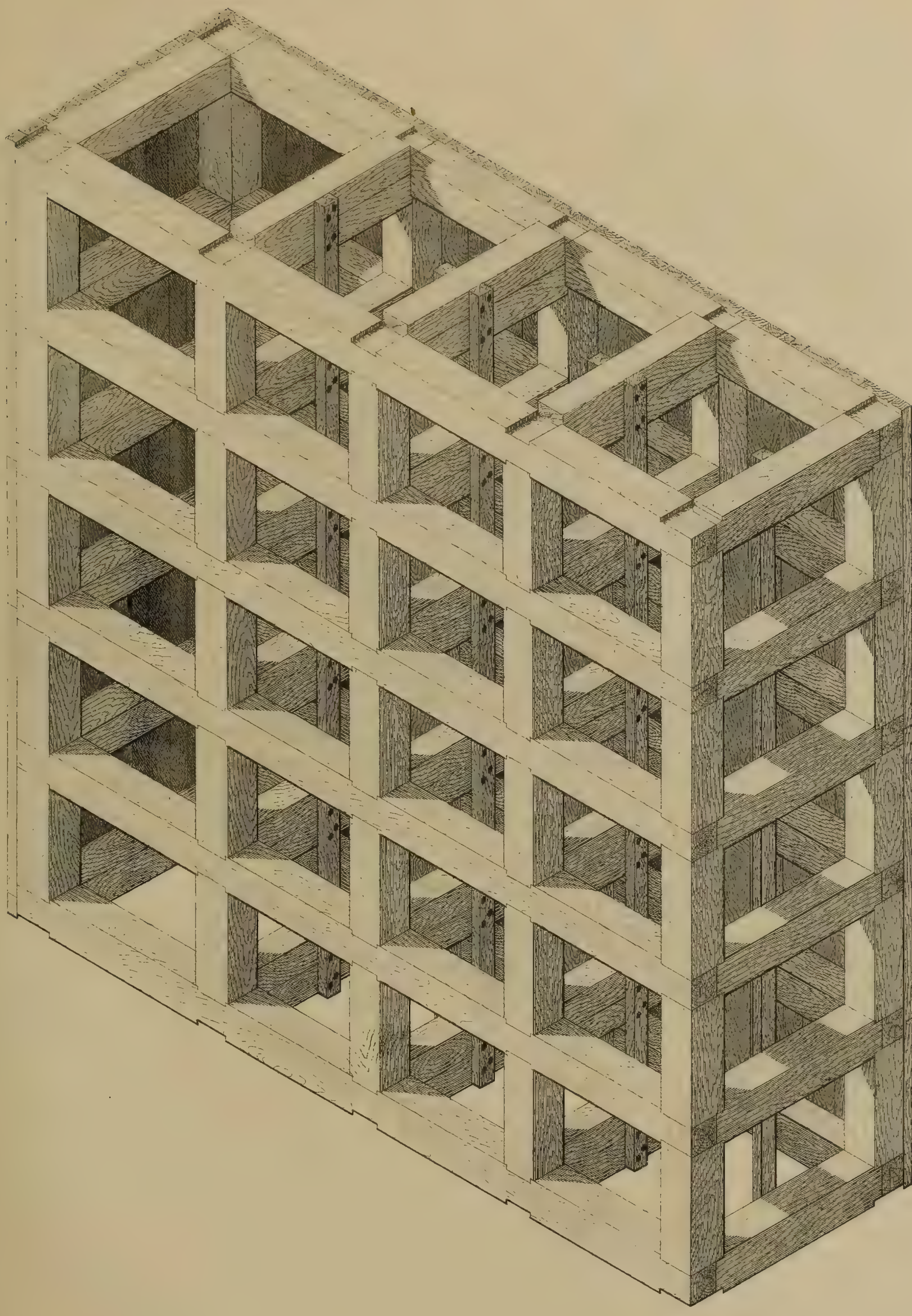
Shaft Timbering.—The timbering consists of framed sets or cribs of square timber, placed horizontally, 4 feet apart, and separated by uprights or posts, introduced between them. Each horizontal set of timbers, therefore, marks about 5 feet in depth. Cross-timbers, for the partitions between the compartments, form a part of every set. The whole is covered on the outside by a lagging of 3-inch plank placed vertically. This method of timbering is illustrated by several drawings on Plates II and III. Fig. 1, Plate II, represents the plan of the shaft, or of one horizontal set of timbers; *S*, *S*, are the longitudinal or sill-timbers; *T*, *T*, the transverse end-timbers; *P*, partition-timbers; *r*, guide-rods, between which the cage moves; *g*, gains, cut in the sill-timbers, to receive the ends of the posts. The sheathing or lagging is seen inclosing the whole frame.

Fig. 2, on the same Plate, is a transverse section through the partition *P* of Fig. 1, between the pumping compartment and the adjoining hoisting compartment, looking toward the latter. In this figure, *G*, *G*, are the posts; *S* the sill-timbers; *P*, the partition-timbers, the ends of which are framed with short tenons that are received in gains cut in the sill-timbers and the ends of the posts; *r*, guide-rod; *l*, lagging or sheathing. Fig. 3 is an end view of the frame, shown in Fig. 1. The single piece *T* forms the end, while the double pieces, *P*, forming the partitions, are seen beyond. The other letters denote the same parts as in Fig. 2.

The outer timbers of each set, that is, the two sides and ends of the main frame, are 14 inches square; the posts, 10 in number, four at the corners and two at each end of the three partitions, are of the same size. The dividing timbers, forming the partitions, are 12 inches square. These partitions, as may be seen in the drawing, are not close, no planking or lining being used on them, but two pieces of timber are employed, one above the other, at each set, leaving open spaces of about 3 feet between the sets. The drawing on Plate III presents an isometric view of a series of these sets, forming together the timbering of the shaft. The lagging or sheathing is removed from the side and end nearest the observer.

The ground through which these shafts pass being generally too unsettled to allow of sinking to any considerable depth without support, the work of timbering is necessarily done from above downward, as the sinking progresses. The method of putting these timbers in place is about as follows: When sufficient ground has been excavated below the last set of timbers, for conveniently putting in another lower set, the long horizontal timbers, or sill-pieces, forming the sides of the set, already framed for receiving the ends, and having gains cut for the posts and cross-pieces, or ties, are lowered down and put approximately in place, being hung by chains to the last set already fixed above. The sill-pieces are usually in two parts, each about 13 feet long, butted together, at the middle, without splice or framing. The ends, cross-pieces, and posts are then fitted as nearly as possible into their proper places. This being done several long, round iron bolts, each made in two parts with a tightening screw in the middle, are passed through the new set and the one, or sometimes two or more, above. Everything being approximately in its place, the new set is adjusted exactly to its proper position, by means of the tightening screws on the bolts by which it now hangs to the set above. The lagging is then put in behind the timbers, and between the plank and the ground are inserted pieces of spiling and wedge-timber, which are driven into place or forced in by jackscrews as firmly as possible. Once fixed in this manner, everything is held by lateral pressure; the bolts by which the set was at first suspended are allowed to remain for a time and then withdrawn, for use in placing succeeding sets.

The shafts on the Comstock timbered in this manner generally stand



Scale: $\frac{1}{60}$.

very well and are maintained in good condition. When movements of the ground force any part of the work out of line, the disturbed sets may be taken out and replaced by new, or re-adjusted without difficulty; and, unless the ground is very bad, with a tendency to move in large masses, the perpendicular line of the shaft may be well preserved.

When it becomes necessary to retimber a shaft or any considerable part of it, the work is usually carried on in one compartment or one-half of the shaft, while the remaining compartments are kept for use in the ordinary operations of the mine.

Nearly all of the deep shafts of the Comstock mines have required more or less retimbering; this has been especially necessary in the deeper portions, near the vein, where the ground passed through is sometimes very heavy, consisting of massive clay, which exerts a tremendous pressure upon the timbers. To withstand this latter it is sometimes necessary to resort to methods still more substantial than that just described. A portion of the Yellow Jacket shaft, passing through uncommonly heavy ground, has been lately timbered with double sets, an outer set inclosing the ordinary single set, giving additional strength to the frame.

The deep shafts of the Gould and Curry, Savage, and Chollar-Potosi mines have all encountered very bad ground in depth, involving large expense for the proper maintenance of the work.

Several hundred feet in each of these shafts have been lately retimbered with 14-inch timbers, placed in sets not four feet apart as just described, but close together, making a solid casing 14 inches thick. In the Chollar-Potosi shaft the sill-pieces are made in two parts of unequal length, one long and one short piece, and in each succeeding set these pieces are so placed as to break joints, the joint occurring opposite one or the other of the timber partitions between the compartments. The corners of the frame are joined together simply with a mitred joint as shown in Fig. 1, Plate II; and the end pieces are placed transversely between them, in such manner that the end of each transverse piece bears with half its thickness against two adjacent sill-pieces.

Figs. 4 and 5, on Plate II, illustrate this method of construction. Fig. 4 is a longitudinal section of a portion of the shaft, showing one end and two partitions. The sill-timbers are laid close together, one upon another: the end-

timbers are placed in similar manner, but breaking joints with the sill-timbers, as shown in Fig. 5, which is an end view of the shaft. The partition-timbers are placed like the end-timbers, one upon another; but their ends are not let into the sill-timbers by any gain or mortice; the sills are dressed smoothly to receive the ends of the partition-timbers, which are then put in place without any framing.

The cost of sinking these shafts varies with the depth and the character of the ground. The actual cost per foot is not easily ascertained, because, in most cases, the expense of sinking the shaft is involved, in the accounts, with other general expenses of the mine, so that an accurate and minute analysis of costs is almost impossible. The most carefully detailed statement concerning the costs of this kind of work are found in the books of the Gould and Curry Company. Their shaft is of the same general character as that described above. It is 24 feet long by 4 feet 8 inches wide, inside measurement. The average excavation is about 7 feet by 26. It is divided into four compartments and timbered, as generally indicated in the foregoing, with 12-inch timbers.

From the available accounts of this work it appears that the cost, per foot, of sinking and timbering the shaft, at a constantly increasing depth, was as follows:[1]

| | | Per foot. |
|---|---|---|
| 225 | feet from surface | $70 21 |
| 200 | feet next following | 100 88 |
| 200 | feet next following | 135 34 |
| 67 | feet next following | 189 50 |
| 187 | feet next following, in 1867 | 224 99 |
| 250 | feet next following, in 1868 | 342 65 |
| 1,129 | feet, costing, on the average | 180 22 |

The shaft had reached a depth of 1,187 feet on November 30, 1869, but the cost of sinking during that year is not published in the last report of the company.

[1] The reader is reminded that these values are expressed in coin.

The following statement shows the details of the cost of 187 feet sunk in 1867, and similar details for 879 feet, the depth attained on November 30, 1867:

| | Cost of 187 feet sunk during 1867. | 879 feet; total depth attained Nov. 30, 1867. |
|---|---|---|
| Excavation | $12,865 00 | $35,189 50 |
| Timber | 1,898 92 | 11,569 59 |
| Lumber | 1,163 94 | 6,623 99 |
| Framing and placing the same | 950 00 | 6,405 81 |
| Pump rods and labor thereon | 367 31 | |
| Powder and fuse | 541 25 | 832 25 |
| Candles | 456 65 | 1,510 95 |
| Picks and drills | 716 05 | 2,757 55 |
| Carmen at surface and below | 2,486 50 | 6,016 50 |
| Machine labor, engineers; oil, and other material consumed in pumping and hoisting; work in setting pumps including $5,000 for resetting engine in 1867. | 20,626 64 | 46,904 52 |
| | 42,072 26 | 117,810 66 |
| 250 feet, sunk in 1868, at $342 65 | ...... | 85,662 50 |
| Total cost of 1,129 feet | ...... | 203,473 16 |
| Or an average cost, for that depth, of $180 22 per foot. | | |

Drifts or Tunnels.—From the stations established in these shafts, drifts or tunnels are run for the purpose of reaching and extracting the ore, or for general exploration of the ground. These levels are usually 100 feet apart, vertically. In the Gould and Curry, where the deeper tunnels have been chiefly for exploring, they are 200 feet apart.

The ground through which they pass is not very firm, being worked sometimes without the aid of powder. The deeper levels, however, have usually required blasting. They almost invariably need to be timbered, especially when the drift is designed for permanent use and not for the sole purpose of prospecting. Occasionally the character of the ground is very troublesome, and the most substantial methods of timbering prove inadequate to its support.

The method employed in timbering drifts or tunnels of the Comstock mines is generally similar to that in use in other mining districts. The timber, however, is all square, varying in size from 8 to 13 inches. Ordinary working drifts, such as those connecting the main shaft with the vein, are about 5 feet wide in the bottom, 4 feet wide in the top, and 7 feet high. They are usually timbered with vertical sets or frames, consisting of two posts, a cap and a sill, or spreader. In the Savage these posts are 7 feet 2 inches high, the cap 3 feet 9 inches, and the sill 4 feet 9 inches long. These sets are placed from 2 to 6 feet apart, according to the nature of the ground. They are covered on the outside with lagging, which is likewise varied according to the condition just named, consisting sometimes of 6-inch scantling, in pieces 5 or 6 feet long, and placed several inches apart; sometimes of 3-inch or 4-inch plank placed close together, inclosing both sides and top, and sometimes the bottom. Lagging, consisting of light scantling, placed several inches apart, is often preferred in heavy, swelling ground, as the pressure breaks in the pieces of scantling before affecting the stronger timbers of the tunnel-sets; by picking down the intruding clay and relieving the pressure, the more expensive timbers are saved. String pieces, usually of square stuff, or 3 inches by 4 inches, are laid in the bottom on the sill-timbers and shod with flat iron $1\frac{1}{2}$ inches wide by $\frac{1}{4}$-inch thick, to serve as track for the drift-cars, and a footway of 2-inch plank is laid between the rails.

Figs. 3 and 4, on Plate IV, illustrate the method of framing the tunnel-sets. Fig. 4 is the ordinary form ; Fig. 5 is a style of timbering in use in the lower level of the Gould and Curry, in passing through very heavy ground. In the cases illustrated, the lagging consists of plank placed closely together.

The following statement, furnished from the books of the Gould and Curry, gives the details of expense in driving and timbering one of the tunnels at the first station of their shaft, 225 feet below the surface, at mouth of shaft, and 1,465 feet in length:

*Cost of Tunneling in the Gould and Curry Mine, including Labor and Materials.*

(Length of tunnel, 1,465 feet, at a depth of 200 to 400 feet below the surface.)

| | Total cost. | Per foot. |
|---|---|---|
| Excavation | $15,932 50 | $10 87 |
| Timber | 3,120 60 | 2 13 |
| Lumber | 549 49 | 37 |
| Spiling | 807 26 | 55 |
| Framing and placing timber | 967 15 | 66 |
| Track iron and screws | 322 93 | 22 |
| Picks and drills | 562 75 | 39 |
| Powder and fuse | 305 12 | 21 |
| Candles | 654 80 | 45 |
| Air boxes | 337 04 | 23 |
| Total | 23,559 64 | 16 08 |

For 938 feet on the second station, at a depth of 625 feet, the cost per foot for same details as furnished in foregoing table was $16 84, the costs of excavation alone being $11 45.

The above statements include nothing for costs of pumping or hoisting. These would of course vary considerably, according to the amount of other works in progress in the mine, among which the total costs of pumping and hoisting might be divided.

On the fifth station, where the rock was much harder, the cost of excavation for 406 feet was $16 92 per foot. For details as given in foregoing, including excavation, $20 93 per foot; and adding the proportionate costs of pumping and hoisting, an aggregate per foot of $36.

On the sixth station, for 297 feet, the cost per foot for excavation alone was $18 30, and for details, as stated in table, $22 94; and adding proportionate costs of pumping and hoisting we have an aggregate of $40 97.

It should be observed that the pumping and hoisting costs are large because at that time but little other work was in progress in the mine.

Stoping or Breasting.—The vein, or its ore-bearing portion, being reached by a drift or tunnel proceeding from the shaft, the work of extraction begins and is almost invariably conducted by overhand stoping. The

first desideratum, under ordinary circumstances, is to connect the new level or station with the one above it by a winze, usually passing through the ore-bearing ground, by which means a circulation of air is effected and the necessary ventilation obtained. The stoping then commences, the work progressing from the level of the new station upwards towards the station next above; the ore, as fast as it is removed from place, being thrown down to the track-level and transported from the stope to the shaft by means of the drift-cars.

The character of the quartz composing these ore-bodies is generally soft, granular, and sometimes friable. It can generally be worked with a pick without the aid of powder, though blasting is sometimes required. The ore is very finely, almost imperceptibly, distributed throughout the mass and with a general uniformity. Formerly the workable ores of the large producing mines were divided into three classes. The first-class, forming now a very small proportion of the whole and yielding, on an average, between $300 and $400 per ton, usually occurring in bunches or pockets in the quartz, is, when so found, removed to the surface in sacks. The second-class ores were such as yielded from $75 to $150 per ton, while the third-class gave from $25 to $50 per ton. More recently, in some of the principal mines, these two classes, the second and third, have been worked together as one without any attempt at assortment. The average yield of these ores varies considerably in the different mines and will be referred to further on. In stoping the ground, therefore, the entire mass of quartz is usually taken down and sent to mill without any classification as to quality, except in the case of first-class ores, when such occur. A rude assortment, however, for the purpose of distinguishing pay-rock from that which is too poor to send to the mill, is sometimes rendered necessary by the occurrence, within the mass of stoping ground, of belts of low-grade rock or bunches of barren quartz, which would otherwise be sent to the surface and worked at a useless cost. An experienced eye, aided, when necessary, by assays, can distinguish by inspection the pay-rock from that which is too poor to yield a profit. The latter then is assorted as well as possible and retained underground for the purpose of filling up the exhausted chambers. This assortment, so far as observed, is not made by hand but by inspection of the ground before breaking, the pay-rock being picked down

separately and sent to the surface, the poor being dumped into the old stopes that remain to be filled up. This is sometimes important, because the necessity of filling up the exhausted stopes is so great, on account of the unsettled character of the ground inclosing the ore-bodies, that when the necessary dead-work of the mine does not supply sufficient material, waste rock must be mined especially for that purpose. This may cost from $1 to $2 per ton, and, consequently, quartz that will not yield a profit exceeding the cost of obtaining waste-rock for filling is usually employed for that purpose. In the Savage mine, where this was observed, the intended minimum value of quartz sent to the surface at date of visit was stated at $23 per ton. By some others, however, ore of much lower grade, and too poor to pay under existing conditions, is taken out to surface and held in reserve, awaiting the time when it may be made available by cheaper methods or reduced prices.

The material inclosing the ore-bodies, or "bonanzas," is of a very unstable character and involves an immense cost in timbering. The great mass of vein-matter is composed of "horses" of country-rock, chiefly propylite, associated with immense sheets of clay. The ore-bodies frequently have selvages of clay of considerable thickness. The whole is soft, yielding, and, owing to its clayey nature, swells on exposure to the air, exerting an enormous pressure. The extraction of such immense bodies of ore, and the opening of such extensive chambers with insufficient support of the country-rock or vein-matter, induces large movements of the surrounding masses. In early days, the immense stopes, though timbered at an extravagant cost of material and labor, were not filled with waste-rock but allowed to remain open. Great caves of ground were, of course, the consequence, extending, in some cases, from the surface to a great depth. It is now the custom to fill up exhausted stopes as soon as possible after the extraction of the quartz, but the necessary outlay for maintaining the mine in proper condition for work is still very large. The means of obtaining waste-rock, as observed in the Savage, where the supply from the dead-work of the mine is insufficient, affords some indication of the character of the ground to be dealt with. For this purpose drifts, 30 or 40 feet long, are driven at convenient points into the country-rock, or, more properly speaking, the barren vein-matter. These drifts are securely timbered. At the end of any such drift a chamber is excavated, about 10 or 12 feet high

and 20 or 30 feet in diameter, the roof, during excavation, being sustained by a few posts and plank. When the chamber has attained the desired dimensions these slight supports are removed. The roof and sides soon begin to swell and fall in, supplying the material which is wheeled out and dumped into the stopes. The loose material being removed from the chamber, the swelling and falling continues for an indefinite period, affording a supply for a long time.

Stope Timbering.—The difficulty of sustaining ground of this nature, by any method of timbering, is not only in itself great, but is much increased by the large size of the chambers rendered vacant by the extraction of the bodies of ore. In the upper portions of the lode, worked several years ago, these chambers were much greater in extent than now. One in the Gould and Curry, 400 or 500 feet in depth and length, is said to have been over 80 feet wide in places, while several others had a width of 45 or 50 feet. At that time, moreover, nearly all of the quartz was removed in working and no provision made for filling the stopes with waste material to replace the ore extracted, leaving these immense spaces to be kept open by timbering, which, to be efficient, even for a time, needed to be of the most substantial sort. Methods ordinarily in use in veins of moderate width and in firm rock were found to be insufficient. To meet the necessities of the case a method of timbering was introduced, which is said to have been devised by Mr. Didesheimer, then of the Ophir mine which, though meeting with some opposition on account of its great cost, has since been generally adopted and is now used by all the mines on the lode. This consists in framing timbers together in rectangular sets, each set being composed of a square base, placed horizontally, formed of four timbers, sills, and crosspieces, 4 to 6 feet long, framed together, surmounted by four posts, 6 to 7 feet high, at each corner, and capped by a frame-work similar to that of the base. These cap-pieces, forming the top of any set, are at the same time the sills or base of the next set above, the posts, as the sets rise one above the other in the stope, being generally placed in position directly over those below.

This somewhat complicated system of timbering may also be described, in other terms, as a succession of horizontal floors, composed of timbers that are framed together in rectangular sets, 4 to 5 feet square, the floors being supported one above the other by posts 7 to 8 feet high. Fig. 2, on Plate IV,

Plate IV.

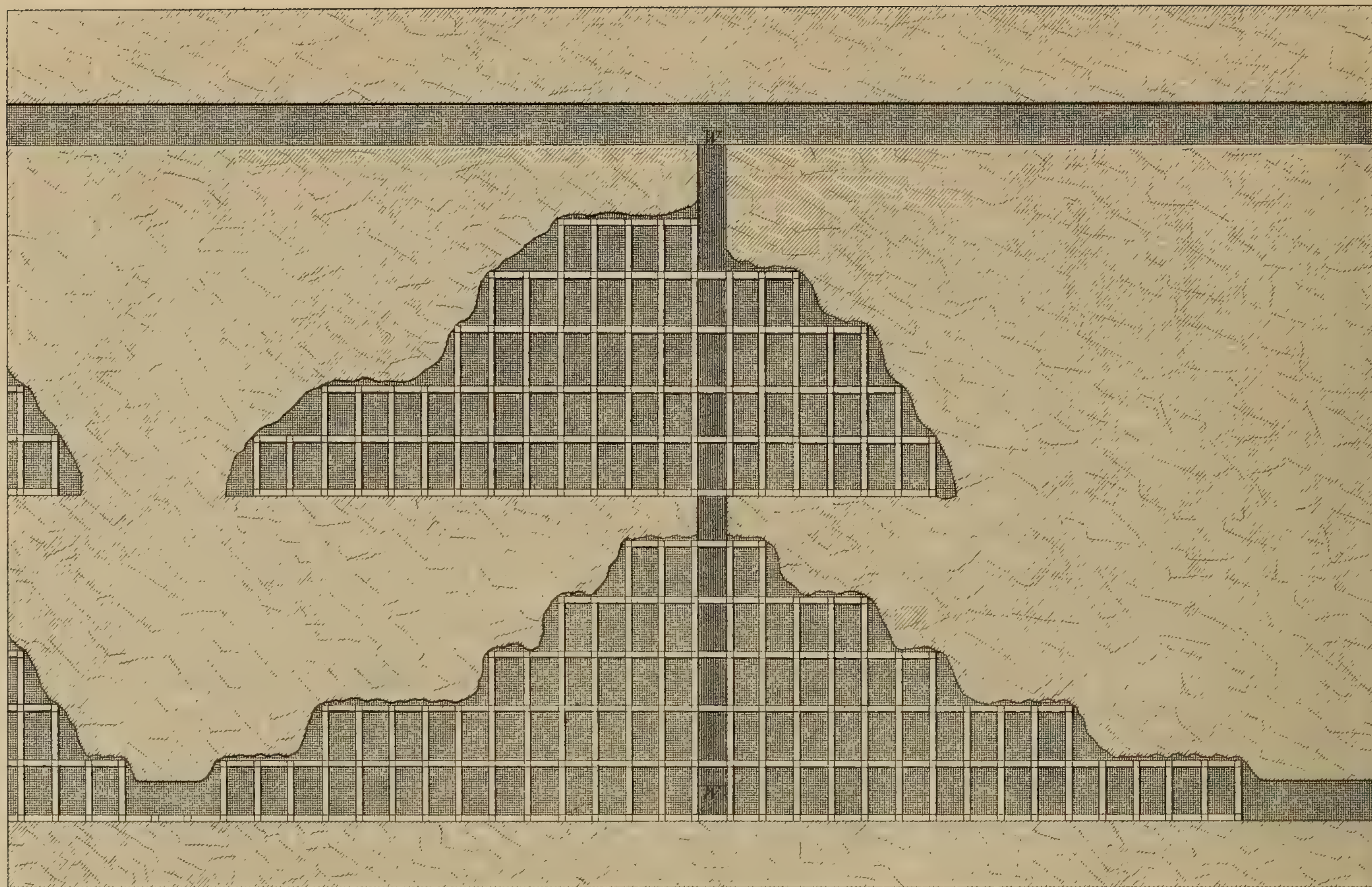
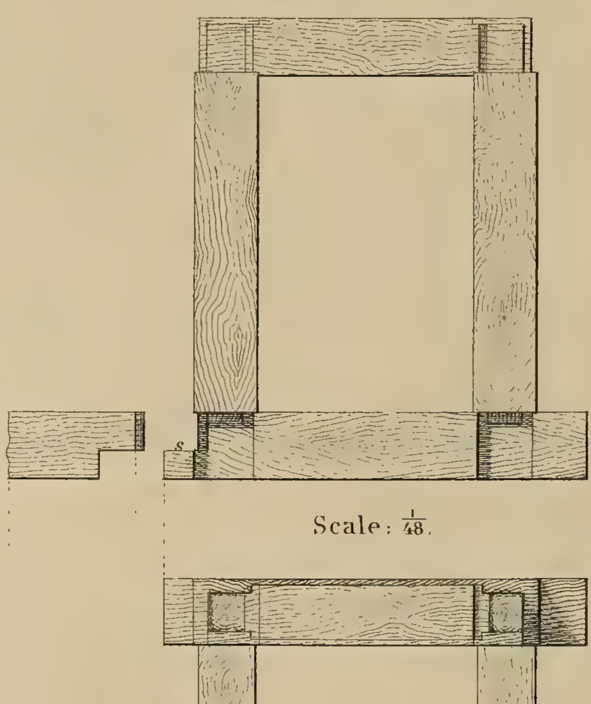



*Fig. 1.*
Scale: $\frac{1}{360}$.




*Fig's. 2.*

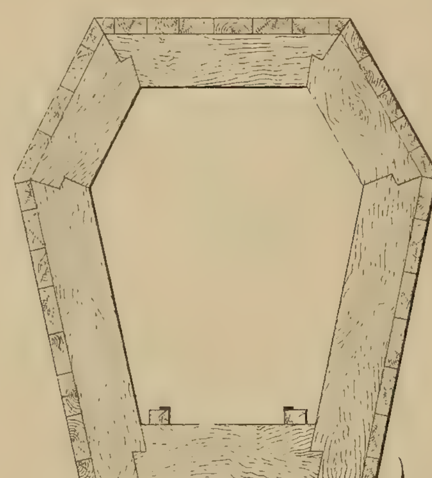


*Fig. 3.*

Scale: $\frac{1}{48}$.

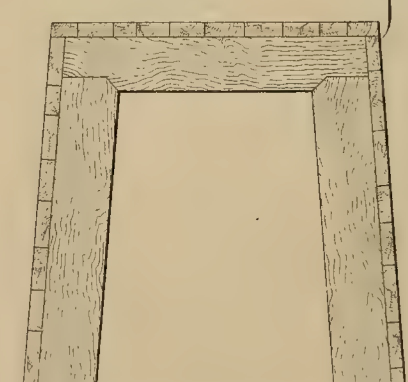


*Fig. 4.*

and the perspective view on Plate V, illustrate this method of timbering in stopes. Fig. 2, Plate IV, presents an elevation and a plan of a single set, showing the details of the framing; while the view on Plate V shows the general arrangement of a series of sets when put together in a stope of the mine.

The timbers are usually of 12-inch stuff, square-hewn or sawed. They are framed with much care so that the various parts fit snugly together. Each piece, excepting, occasionally, the ground-sill or foundation-timber of a new series of floors, as explained further on, is cut and framed separately. This is sometimes done by hand, sometimes by machinery. The latter is the case at the Savage, where a system of circular saws and planers, adjustable by set-screws, is so arranged that the piece of timber, held firmly by appliances which permit of its being easily revolved or moved to and fro, can be brought against them, the saws cutting the tenons of any desired dimensions and the planers cutting the shoulders, either square or beveled.

In the Savage mine the posts of the sets, above described, are 7 feet 2 inches high, including the tenons. These latter, 8 inches square or 8 by 10, are 9 inches long on the upper end of post, and 2 inches long on the lower end; and as the caps and sills have ½-inch shoulders cut for the admission of the ends of the posts, there remain 6 feet 3 inches in the clear between sills and caps of each set. The sills and caps, 3 feet 9 inches in the clear, also have short tenons on each end and shoulders cut to receive the ends of the posts and horizontal cross-pieces.

In some cases this method of framing is varied to suit the varying conditions of the ground, so that, if the pressure is chiefly a vertical one, the tenons of the posts are cut as just described, bringing the ends of each post in direct contact with its neighboring post, above and below, without introducing between them the tenons of the horizontal timbers, which would offer less resistance to a pressure at right angles to the fibre of the wood; while if the pressure be lateral instead of vertical the tenons of the posts are made short and those of the horizontal timbers long, so that the latter may press directly against each other without the intervention of the post-tenons.

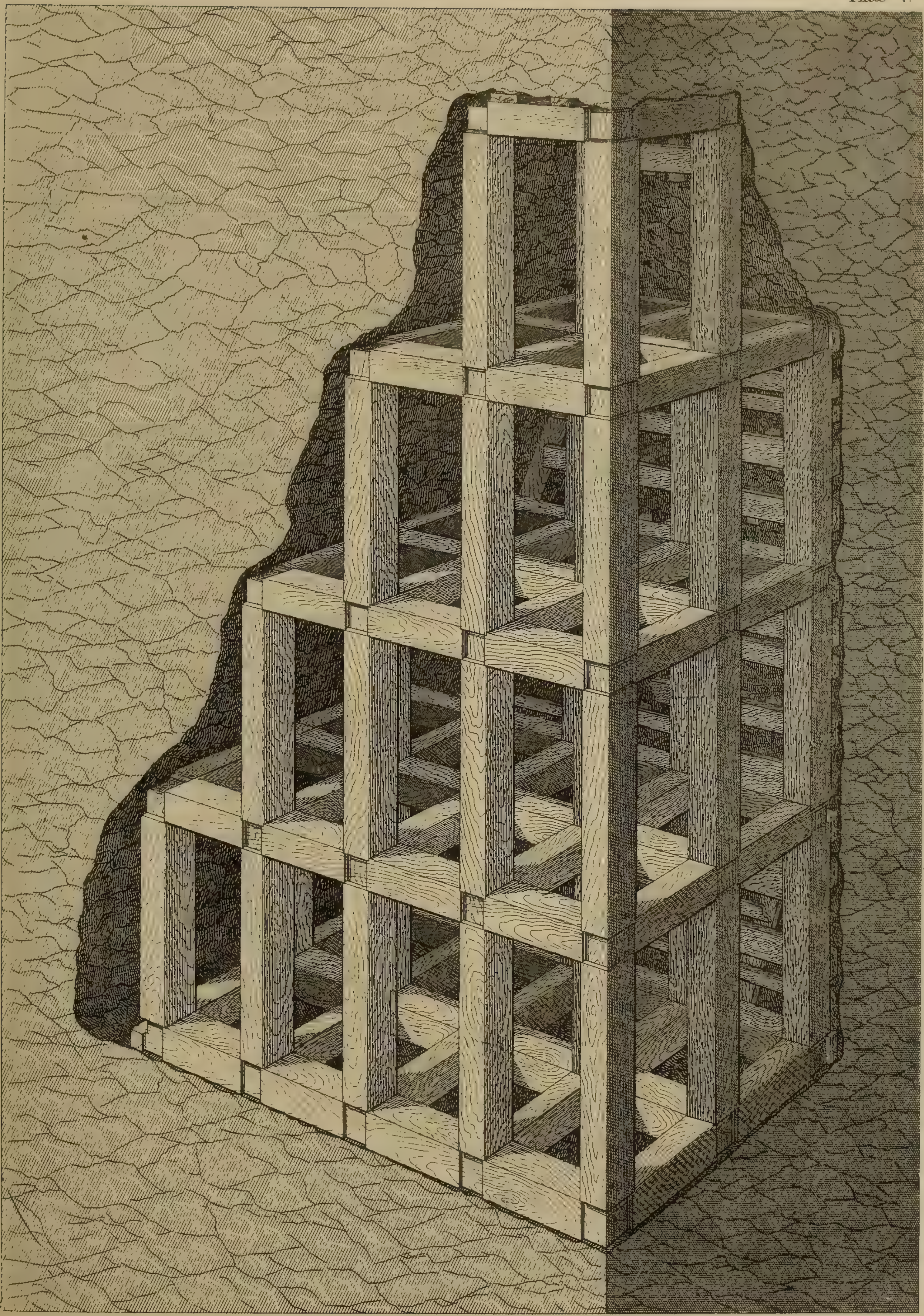
The stoping is, as already observed, all carried on overhand; that is, a station, or level, is opened under the body of ore to be worked out and the

progress of mining goes on from below upwards. In commencing the timbering of a stope, as for instance, at a new station or level, commonly called the "track-floor," the ground-sills are usually laid parallel with, though sometimes at right angles to, the direction of the stope, or the walls enclosing the body of ore, and are frequently timbers of sufficient length to serve as the sill for several sets. The end of a ground-sill is so framed, projecting a few inches beyond the last post, that the next adjoining sill-timber, to be laid as the stope progresses, may be spliced to the one already in position, the joint being made under the post, as shown at *s* in Fig. 2, Plate IV. The sills being laid and the cross-pieces adjusted in position, the posts are raised and the cap-timbers are fixed in their places, everything being fitted carefully and closely together. No pins, bolts, or keys are employed in the framework. The walls of the chamber are sustained by a lagging of plank, inserted between the timber frame and the adjacent rock. This lagging consists of 3-inch or 4-inch plank, laid next the timbers and wedged, when necessary, by spiling. In time the lateral pressure of the ground holds everything firmly in place.

After a set of timbers has thus been introduced and finally put in place, a floor of 3-inch planking is laid upon it, to serve as a footing for the workmen in the space above. From this comes the local term of "floor" to designate any particular place or point in the mine; the stations or levels, about 100 feet apart, being numbered from the surface down, first, second, third, and so forth, the floors being similarly numbered upward, between the several stations or track-floors.

In working a stope thus the whole width of the workable ground in the body of ore is taken down at once and the timbering supplied in its place, the advancing breast of the stope being carried forward from wall to wall; in bodies of ordinary width this is from 10 to 20 or 25 feet, requiring, therefore, in cross-section from two to six sets of timber, like those just described.

In commencing a stope on the level of a new station the ground-set or first floor is put in, and as soon as sufficiently advanced in the direction of the stope the next set above is placed on the first of those below. Both then progress at about the same rate, the lower floor being kept sufficiently in advance of the upper to furnish platform and working room for the men above. As the work progresses, one set or floor is raised above the other until the



Scale: $\frac{1}{48}$.

station above is reached, each floor being kept a little in advance of the one next above, as indicated in the drawings on Plates IV and V.

When it becomes necessary, on account of the unsettled character of the ground, or for other reasons desirable, to extract the body of ore as speedily as possible, it is not uncommon to commence at the same time a floor on the level of the station and another floor halfway between the given station and the one above. For this purpose a winze is sunk from the upper station to the one below. From this winze the stopes are started, one on the lower station and one 50 feet higher. The lower series of floors, usually six or seven in number, rising one above the other, arrive at length directly under the 50-foot sill, as the lower floor of the upper series is termed. By this time the mass of timbering is held in place by lateral pressure with sufficient security to allow of introducing, without difficulty, the timbers to be placed directly under the 50-foot floor. Fig. 1, on Plate IV, is an illustration of this proceeding. The main body of stopes, visible in the drawing, have been started and carried on from the winze, W, that connects the upper with the lower level. The stoping on the extreme left has proceeded in similar manner from another winze, further to the left, the stopes advancing to meet each other. After the available ground has been exhausted the plank of the floors are removed for use elsewhere, and the vacant chamber filled with waste material.

The expense of this work is, of course, very great, both for material and labor. The cost of the timber is from $30 to $40 per thousand feet,[1] board measure, and the consumption is enormous, making the timbering one of the largest items of expense in the Comstock mines.

In the Gould and Curry the costs of framing (by hand) the mining timbers just described were from 46 to 60 cents apiece for posts, 35 to 40 cents for caps, 25 to 30 cents for cross-pieces, or girths, and $1 20 to $1 50 for sills. Shaft-timbers cost, at same mine, framed by hand, about $20 per set; tunnel-timbers $1 to $1 50 per set for framing alone, not including any costs of placing under ground.

In the Gould and Curry, in 1864, the supply of timber for use in the

[1] These prices have been reduced since the completion of the Virginia and Truckee railroad.

mine cost $160,488 76, or nearly $2 50 per ton of ore produced. In 1865, for same purpose, were expended $147,382 92, or over $3 per ton.

The following statement, prepared from the annual reports of the Savage Mining Company, shows the consumption and cost of timber used in their mine during three years:

| Year ending June 30— | Timber. | Lumber. | Spiling. | Total cost of materials. |
|---|---|---|---|---|
| | *Feet, b. m.* | *Feet, b. m.* | *Pieces.* | |
| 1867 | 1,785,956 | 499,704 | 10,307 | $69,982 59 |
| 1868 | 2,075,567 | 544,599 | 15,028 | 82,785 65 |
| 1869 | 1,352,716 | 363,388 | 10,057 | 51,102 18 |

The cost as stated in the foregoing applies to the material alone, without including the labor of framing and putting in place. It covers the whole amount of timber and lumber used in the mine, in all the various departments of the work, and may be analyzed about as follows:

*Cost of Timber and Lumber consumed in the Savage Mine per ton of ore produced.*

| During year ending June 30— | In extraction of ore. | In prospecting work. | In accessory work. | In improvements. | Total per ton. |
|---|---|---|---|---|---|
| | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* |
| 1867 | 63 | 12 | 13 | 10 | 98 |
| 1868 | 51 | 13 | 24 | 06 | 94 |
| 1869 | 42 | 16 | 34 | 03 | 95 |

In the Hale and Norcross Mine the cost of timber during the past two or three years is shown by their reports to be about $1 per ton of ore produced.

Ore Extraction.—The ore, as it is worked out or broken down by the miners in the stope, is thrown down to the track-level of the station below, either falling upon the floor of the drift or into a receiver or bin, whence it is loaded into the drift-car and carried to the shaft. There the car, containing

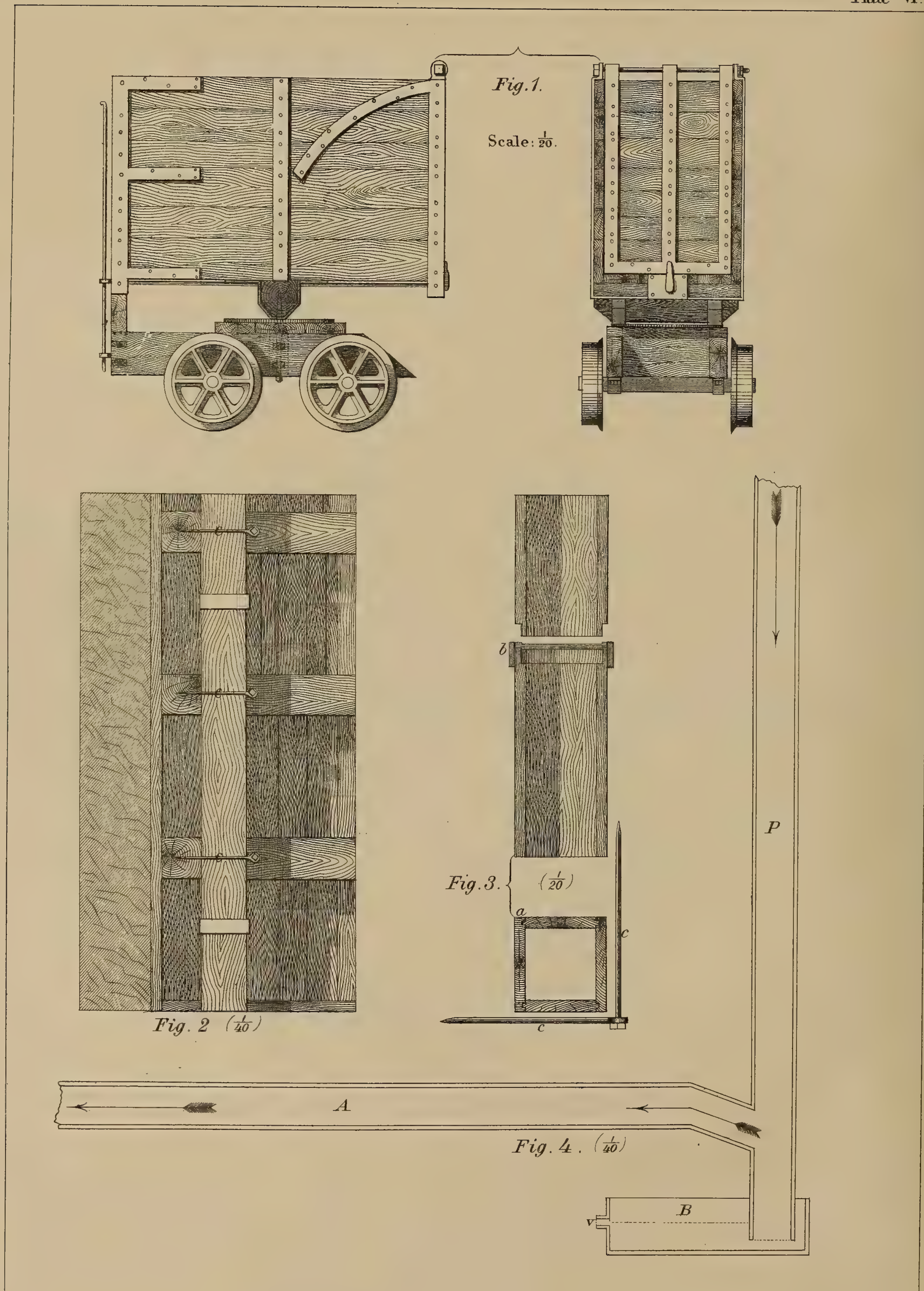


Fig. 1.
Scale: $\frac{1}{20}$.
Fig. 2 $(\frac{1}{40})$
Fig. 3. $(\frac{1}{20})$
a
b
c
c
P
A
Fig. 4. $(\frac{1}{40})$
B
v

its load either of ore or waste-rock, is placed upon the cage or platform in the shaft and raised to the surface, where it is run from the cage on to another track and so conveyed to the appropriate ore-bin or waste-dump, according to its character, and thus delivered of its load without any intermediate handling.

The car in general use in the Comstock mines is made of wood and has a capacity of about 1,600 or 1,800 pounds. That employed at the Savage may serve as an example. Fig. 1 on Plate VI presents an elevation of the side and front end of one of these cars. The box is made of plank $1\frac{1}{2}$ to 2 inches thick, lined with sheet-iron and strengthened with iron bands on the outside. It is 3 feet 10 inches long, 2 feet wide, and 2 feet 4 inches deep, inside measurement. The truck on which it is supported is a stout frame of four timbers, the two longitudinal pieces having their front ends beveled off to admit of the car being dumped. A cross-timber near the middle of the frame supports the car, and an iron pin attached to the car-bottom passes through the same, serving as a pivot on which the box may be turned to either side and dumped. Another cross-timber on the frame supports the hind-end of the box. The wheels are cast iron, about 12 inches in diameter, turning on the axles, which are fixed on the truck. A little cap may be screwed on to the wheel over the end of the axle, to retain the oil and exclude the dirt. The track is about 18 or 20 inches wide, so that the wheels are under the car-box. The front end of the car is hinged at the top to swing as a door for the discharge of the contents. It is closed by a button that may be turned up to confine the door or turned down to release it; the button being fixed on an iron rod passing under the car to the back end, is controlled by the man who pushes the car before him. An iron rod at the back end of the car which, when adjusted for that purpose, serves to prevent the box from swinging on its pivot, is so connected with the rod on which the button is fixed that the door of the car may be opened and the box made free to swing to either side by one and the same movement on the part of the carman. The weight of this car is from 400 to 500 pounds.

Hoisting Cages.—Cages, or platforms, are generally employed in the hoisting compartments of the mine-shafts for the ascent or descent of the underground laborers, and of the drift-cars bringing rock or ore to the surface.

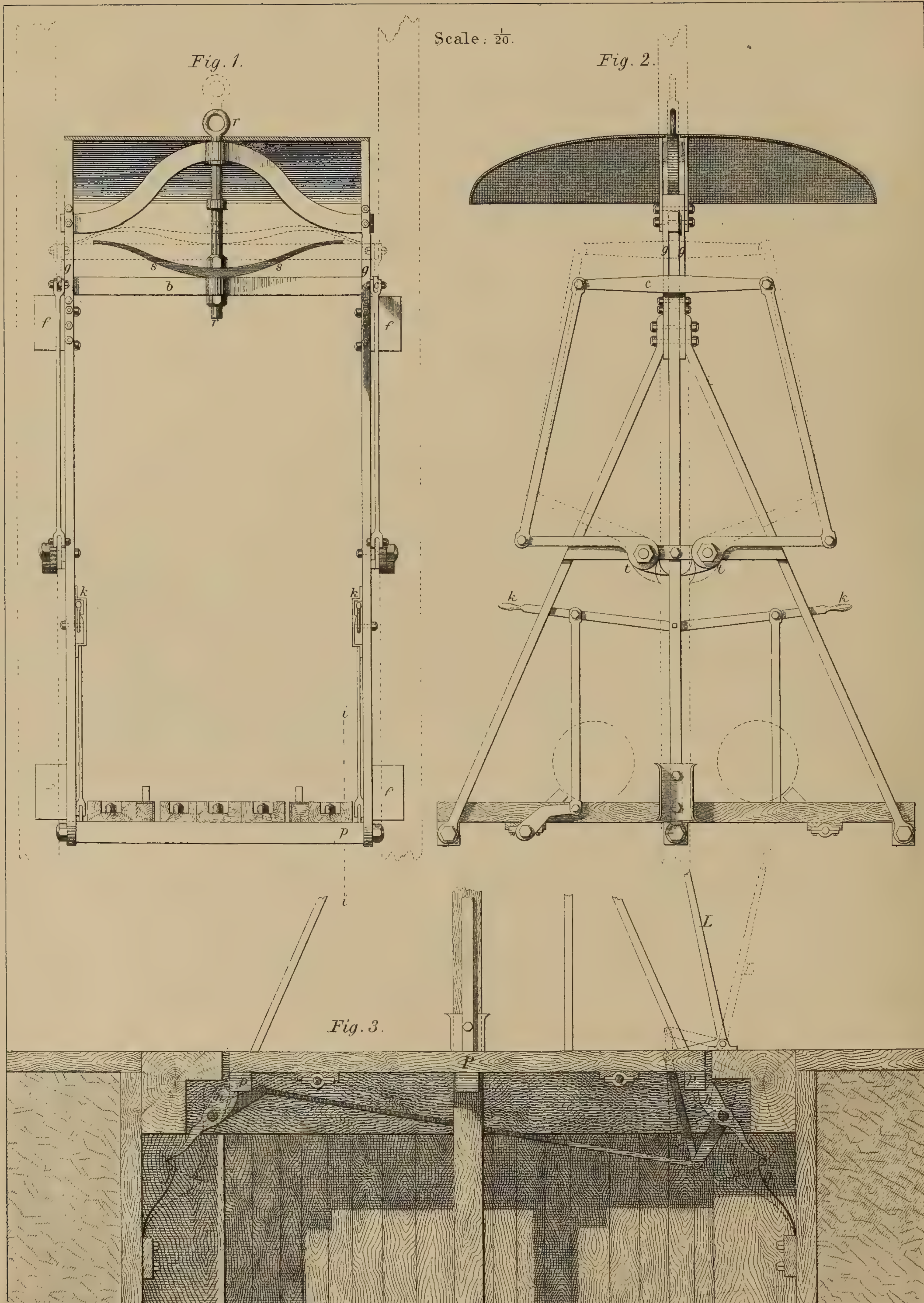
The construction of the cage employed at the Savage mine for this purpose is illustrated by Figs. 1 and 2 on Plate VII.

The bottom of the cage is a simple platform, 5 or 6 feet square, according to the size of the compartment, formed of wrought-iron bars firmly joined together and covered by a floor of wood, provided with pieces of track iron on which to receive the car. The two sides of the cage, above the platform, which are next the guides in the shaft, are formed of a simple but stout framework of iron, 7 or 8 feet high, joined at the top by a central cross-bar connecting them, above which is a stem or vertical rod of iron by means of which the whole is attached to the hoisting cable. The two sides of the cage, between the frames, are open for the admission or exit of the car, men, or material with which the cage is loaded.

The cage is guided in its movement in the shaft by two vertical strips of wood, or guide-rods, 4 inches by 6 inches in size, attached to the lining of the shaft, one on each side of the cage, and extending from the surface to the bottom.

Attached to the cage on each side, near the top and bottom, are iron flanges, *f*, Fig. 1, commonly called "ears," so made as to embrace the wooden guide-rods already referred to. The mode of construction of these flanges is very simple, and may be easily understood by reference to the figure. The wooden guide-rods are in general use and have replaced those of iron that were formerly employed in some places. They are better adapted to the action of the "safety catches" described in a following paragraph, and permit an easier movement of the cage while allowing sufficient play to prevent the cage from binding or sticking fast, an accident which is sometimes liable to occur whenever the shaft or the guides are a little out of line, and which is likely to be followed by serious consequences.

Some of the cages in general use are constructed as simply as possible, with the only end in view of providing a suitable platform for the support and transportation of the car or other load. Others are constructed in different mines with various appliances to insure safety, so that in case the cable or winding apparatus should break, the progress of the cage may be arrested wherever it may be at the moment of the accident, and so preserved from falling to the bottom with its load. The various devices applied for this purpose


Scale: 1/20.
Fig. 1.
Fig. 2.
Fig. 3.
r
s
s
g
g
b
f
f
k
k
i
p
c
t
t
L
P
h
h

to these "safety cages" differ a good deal in detail of construction, and, probably, in degree of efficiency, but they generally depend on a spring so fixed, with regard to the rod by which the cage is attached to the cable, as to be compressed while the weight of the cage exerts any strain upon the cable; but if that strain is relaxed by the breaking of the cable or other parts of the winding machinery the spring is permitted to act upon some mechanical contrivance by means of which stout iron teeth are forcibly projected against, or caused to grasp, the guides along which the cage is moved. These teeth are so arranged that when the spring is compressed they move along the guide without coming into contact with it, but when the spring is relieved act with the greater force the heavier the load on the cage.

The contrivance on the cages used at the Savage mine may be seen in the drawings on Plate VII. A horizontal movable bar of iron, *b*, Fig. 1, crosses the cage near the top, from side to side. The lifting-rod, *r*, by which the cage is attached to the cable, passes through this bar and is so connected with it that the latter may move upward and downward between guides, *g*, *g*, according as the rod is raised or suffered to fall. When the rod is raised by the strain of the cage on the cable the bar is elevated, but if the strain on the cable is relaxed, the rod consequently falling, the bar moves downward and a strong spring, *s*, is introduced to force it down whenever this condition occurs. To each end of this cross-bar, on opposite sides of the cage, is attached at right angles a shorter horizontal bar, *c*, Fig. 2. To each extremity of each of these last-named bars, *c*, *c*, is attached one end of a system of levers by means of which two stout iron teeth or "dogs," *t*, *t*, at the other end, are thrown against the guide-rods in the shaft when the cross-bar is down, or drawn from the guide-rods when the cross-bar is raised.

In Fig. 2 this contrivance is shown in such manner that the action of the levers can be readily traced. The cage not being suspended by the cable the cross-bar is depressed and the teeth are almost in contact with each other, in the position in which they would grasp the wooden guide-rods were the cage in the shaft without its usual support. The dotted lines indicate the position of the levers and teeth when the cage is hanging on the cable and the cross-bar, *b*, is raised.

This kind of safety catch has been proved to be very efficient. In the

month of February, 1867, a cage was descending at usual speed, with thirteen men, when by a singular accident the cable became detached from the lifting rod of the cage. The latter stopped almost immediately, but with so little shock that the men on the cage were not even led to suppose that an accident had happened. The engineer, not perceiving any difficulty, continued to unwind the cable, which, passing down between the cage and the side of the shaft, attracted the attention of the men, who rang to stop. Another cage was sent down in the adjoining compartment, when the state of the case was discovered and the men relieved.

ECCENTRIC SAFETY ATTACHMENT.—Another appliance for insuring safety, more common, and by some preferred to the one just described, is that known as the "Eccentric." This is illustrated by drawings on Plate VIII. The general form of the cage may be the same as in the case already described. The contrivance for insuring safety consists in two round shafts, or rods, *a*, *a*, which extend across the cage from side to side, parallel to the central cross-bar, *b*, of the main frame. They are supported by the main frame of the cage in such manner that they may revolve freely, and they extend beyond the sides of the cage so that their ends are opposite the wooden guide-rods, *c*, *c*, of the hoisting shaft. To each end of these two rods are attached the eccentrics, *d*, *d*, which are circular pieces of cast iron, supported, as their name implies, in such manner that the center of the shaft, *a*, or axis of revolution, does not coincide with the center of the circle. That part of the circumference of the circle which is nearest to the point of support is smooth, but that which is more remote is furnished with teeth, so that, when the shafts, *a*, *a*, are in such position that the smaller diameter of the eccentrics is turned toward the guides, they may move freely, up or down, without coming into contact with the guides; but if the shafts, *a*, *a*, be turned so as to present the larger diameter of the eccentrics to the guides, the latter are grasped by the teeth just referred to. Each eccentric rod is furnished with a chain, *e*, one end of which is fixed to the rod, and, winding round it, is attached at the other end to a bolt, which passes through the cross-bar, *b*. Between the head of the bolt and the cross-bar, a strong steel spring, *f*, is interposed, the tendency of which, when compressed, is to cause the shaft, *a*, to revolve in such manner as to bring the teeth of the eccentrics into contact with the guides. The chains, *g*, *g*, by which the cage

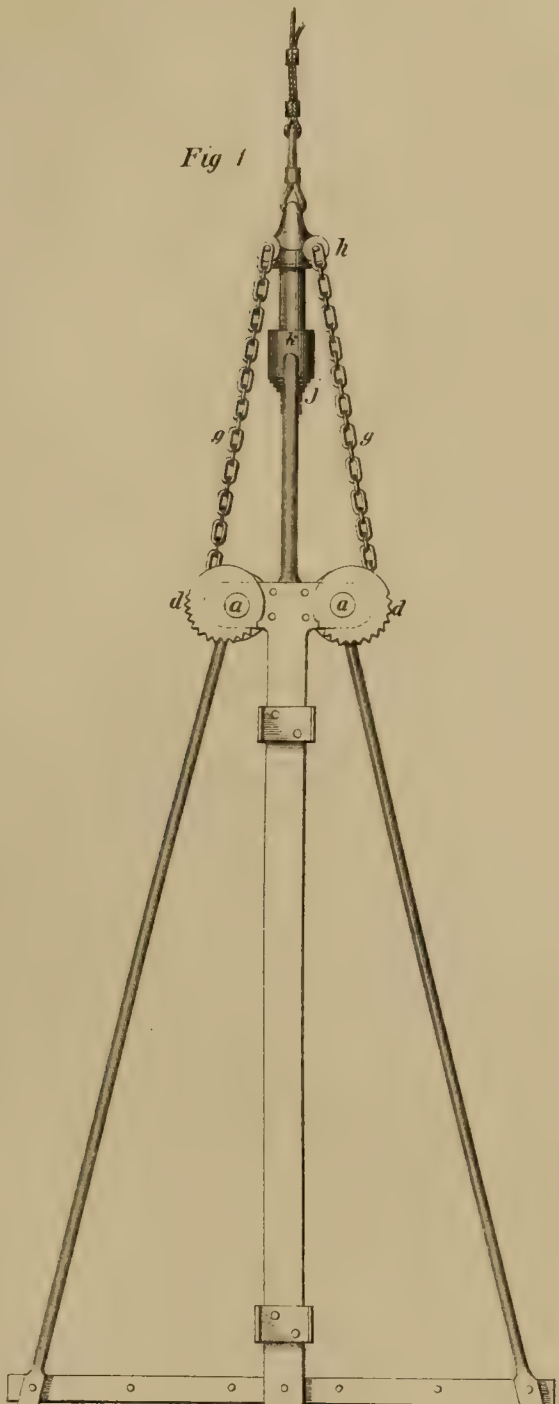



Fig. 1

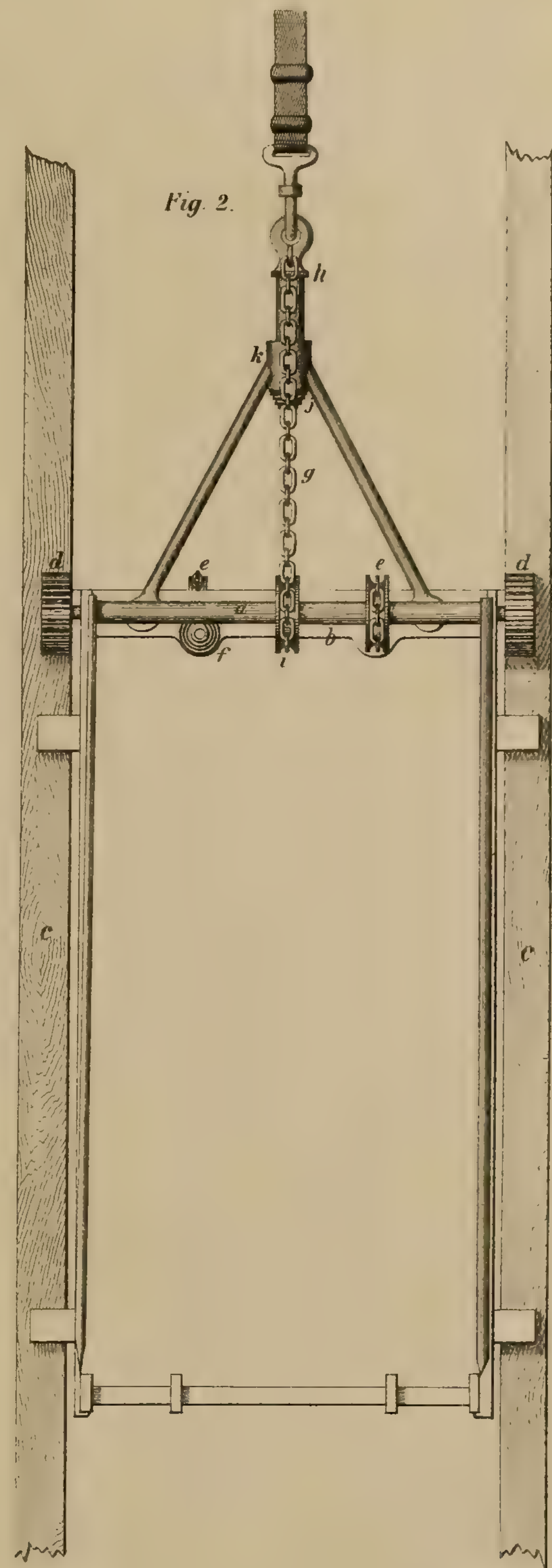



Fig. 2

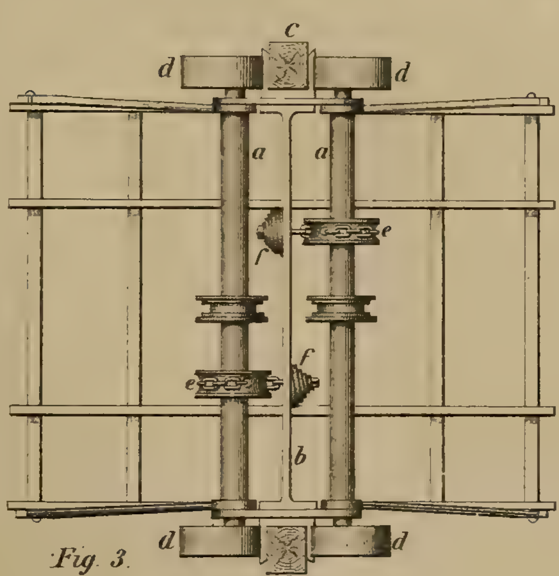



Fig. 3

Scale: $\frac{1}{27}$

is supported, are fixed at one end to the upper part of the lifting rod, *h*, while the other end passes around the shaft, *a*, as seen at *i*, Fig. 2, and is attached to it, so that the tendency of this chain, while there is any strain on the cable, is to revolve the shaft, *a*, in such manner that the eccentric teeth are turned away from the guides. If, however, by the breaking of the cable or other reason this strain be relaxed, the springs, *f*, *f*, act upon the shaft, *a*, and turn the eccentric teeth toward the guides, thus preventing the fall of the cage. This movement is assisted by the spring, *j*, which is interposed between the bottom of the lifting rod, *h*, and the ring, *k*, through which the rod passes.

This style of safety attachment has been repeatedly tested by accidents which, but for the efficiency of the contrivance, would have proved fatal to life.

The cage is sometimes furnished with a hood or covering of iron, usually made of boiler-plate, for the purpose of protecting the men from the danger of the cable, if broken, or other bodies falling in the shaft. Such a hood is shown in Figs. 1 and 2, Plate VII. It is usually, though not in the case illustrated, hinged in the middle, so that the two sides may be turned up when it is desired to send down long timbers on the cage. The necessity, for other reasons, of having the hood made in two hinged parts was shown by an occurrence in the Gould and Curry mine, some time since, when two men, who were being lowered to the bottom of the mine, found themselves descending below the surface of the water, which had risen higher than they had supposed. They endeavored to climb upward, but the hood not being a hinged one they were securely imprisoned in the cage. Fortunately a signal reached the engineer in time to save them from drowning. Iron hooks underneath the hood serve to keep it securely closed when so desired.

When the cage arrives at the surface it is desirable that it should be sustained at a fixed point, on a level with the floor at the landing of the shaft, so that the car may be easily run off or on. For this purpose there are supports arranged, on which the cage may rest while standing at the shaft-mouth. These supports consist of four tappets, two on each side of the shaft, just below the floor. They are fixed upon a light iron shaft which may be partly

revolved, turning the tappets upward entirely out of the path of the cage when the latter is to be lowered. The cage in ascending, striking the tappets, raises them in passing, when they fall again into place and the cage is lowered upon them. When the cage is ready to descend again it is first raised a few inches, the tappets are turned up out of the way by means of a lever within reach of the lander, or man who attends to the car, and held in that position until the cage has passed down. This contrivance is illustrated in Fig. 3, on Plate VII. The drawing represents a section of the mouth of the shaft and of the platform of the cage, taken through the line *i i* of Fig. 1.

*P*, Fig. 3, is the platform of the cage, and *p*, *p* are the cross-bars of the frame, to which the tappets, *h*, *h*, afford support when in the position shown in the drawing. The tappets are fixed on light, round shafts below the floor, and may be revolved slightly toward or from the cage by means of levers, one end of which, the handle *L*, is within reach of the attendant, and the action of which may be readily understood by an inspection of the drawing. The dotted lines indicate the position of the various parts of this contrivance when the lever *L* is drawn back, so as to turn the tappets out of the way of the descending cage. By this movement the springs, *j*, *j*, are forced into the position indicated by dotted lines, and cause the tappets to return to their former place as soon the lever *L* is released by the attendant. A similar arrangement is sometimes employed at the different stations in the shaft, though usually, when hoisting is in progress from any particular station, it is common to place a few planks across the shaft for the cage to rest upon.

The car, while on the cage platform, is held securely in place, sometimes by hooks fitting into staples in the body of the car, sometimes by tappets, which being fixed under the platform may be turned up so as to block the wheels of the car or turned down again to permit its exit. These blocks are controlled by handles, *k*, *k*, on the sides of the cage, as may be seen in the drawings. It will be observed that the handles not only extend in opposite directions but are attached to opposite sides of the cage, as shown in Fig. 1.

The speed with which cages are hoisted varies in the different mines from 300 or 400 to 800 feet per minute, or even more. With an average

speed of 400 feet per minute, which is employed at the Savage, it is easy to see that the capacity of the shaft is large. Twelve cars per hour, bringing 10 tons of rock to the surface, can be raised from depths now reached in each compartment when necessary; a hoisting capacity fully equal to the means of transportation employed below ground, between the stopes and the shaft. Under ordinary circumstances this dispatch is not required or attained. Three hundred tons per day, including both ore and waste-rock necessarily hoisted, is about the average duty required of the Savage shaft during the past two or three years; and this is easily performed.

In the Savage, Gould and Curry, and other deep shafts of four compartments, two of the three devoted to hoisting are commonly used for raising ore or cars from the stations connected with the stopes, while the third compartment is reserved for use in sinking the shaft, inasmuch as the bottom must be kept clear of rock and water in order that the work of sinking may proceed without interruption. Although the timbering of the shaft usually progresses with about the same speed as the excavation of the ground, it sometimes happens that the bottom is considerably below the last set of timbers and for this reason in some shafts a bucket or kibble is used in the sinking compartment, because that does not require guides or completed timbering as does a cage. Such is the case in the Gould and Curry, where in the sinking compartment, as it is called, a bucket is used for hoisting from the bottom, while cages are employed in the other compartments. In the Savage, however, a cage is used in the sinking compartment, its use being made feasible by a timber framework, made to fit the compartment and move between the guides as the cage itself does. This frame is attached to the cable, and is of such length that the platform on which the car stands may be lowered, at the bottom of the shaft, eight or ten feet below the last set of timber, while the upper end of the frame remains confined between the guides. The car thus receives its load at the deepest point as easily as a bucket might, and discharges at the surface with much greater convenience.

The transportation of the men between the surface and the underground works is done entirely by means of the cages. No ladders are employed for the purpose. Twelve men ride at once upon the platform. A short time suffices to put the entire force of laborers underground or to take them out.

Accidents sometimes occur, but they are usually the results of carelessness on the part of the sufferers, either in climbing upon or crowding the cage, or otherwise violating the simple rules of safety.

The winding apparatus and other machinery employed at the surface in hoisting and pumping will be described after reference to the pumps placed in the shafts.

PUMPING MACHINERY.—The pumps usually employed in the several deep shafts of the Comstock lode are all of the same general character, and do not differ essentially in principle from those used in deep mines in other countries. They are either lifting pumps or force-pumps. In a complete set of deep pumps the two kinds are combined, the former being applied to raising the water from the bottom of the shaft to a height adapted to the capacity of a single pump, the latter for forcing the water thence upward to the point of discharge.

*The Lifting Pump*, Fig. 7, Plate IX, consists of a cast-iron cylinder, or "working barrel," from 8 to 12 inches in diameter and from 8 to 12 feet long, smoothly turned inside, in which a closely-fitting piston, *P*, that has an upward-opening valve, *v*, may be caused to move up and down by means of a rod to which it is attached. At the bottom of the cylinder is a valve, *V*, opening upward, by means of which the water once drawn from below into the cylinder is retained there. Below the cylinder is the suction pipe, *S*, dipping below the surface of the water to be lifted. Above the cylinder is an iron pipe or column of elevation, *C*, in which the water is raised, by the upward movement of the piston, to any desired height. When the piston in the cylinder is moved upward, its valve remaining closed, and the lower end of the suction pipe being immersed in the water, the pressure of the exterior air causes the water to rise in the suction pipe, *S*, and to pass through the retaining valve, *V*, at the bottom of the cylinder, in accordance with the well-known principle involved in all suction pumps. On the downward stroke of the piston the retaining valve, *V*, at the bottom of the cylinder, closes, while the valve, *v*, in the piston, opens and the water passes through the piston. On the succeeding upward stroke the water, now above the piston, is lifted by it, while a new supply is drawn into the cylinder in the manner just described, to be lifted by the next upward stroke.

Plate IX

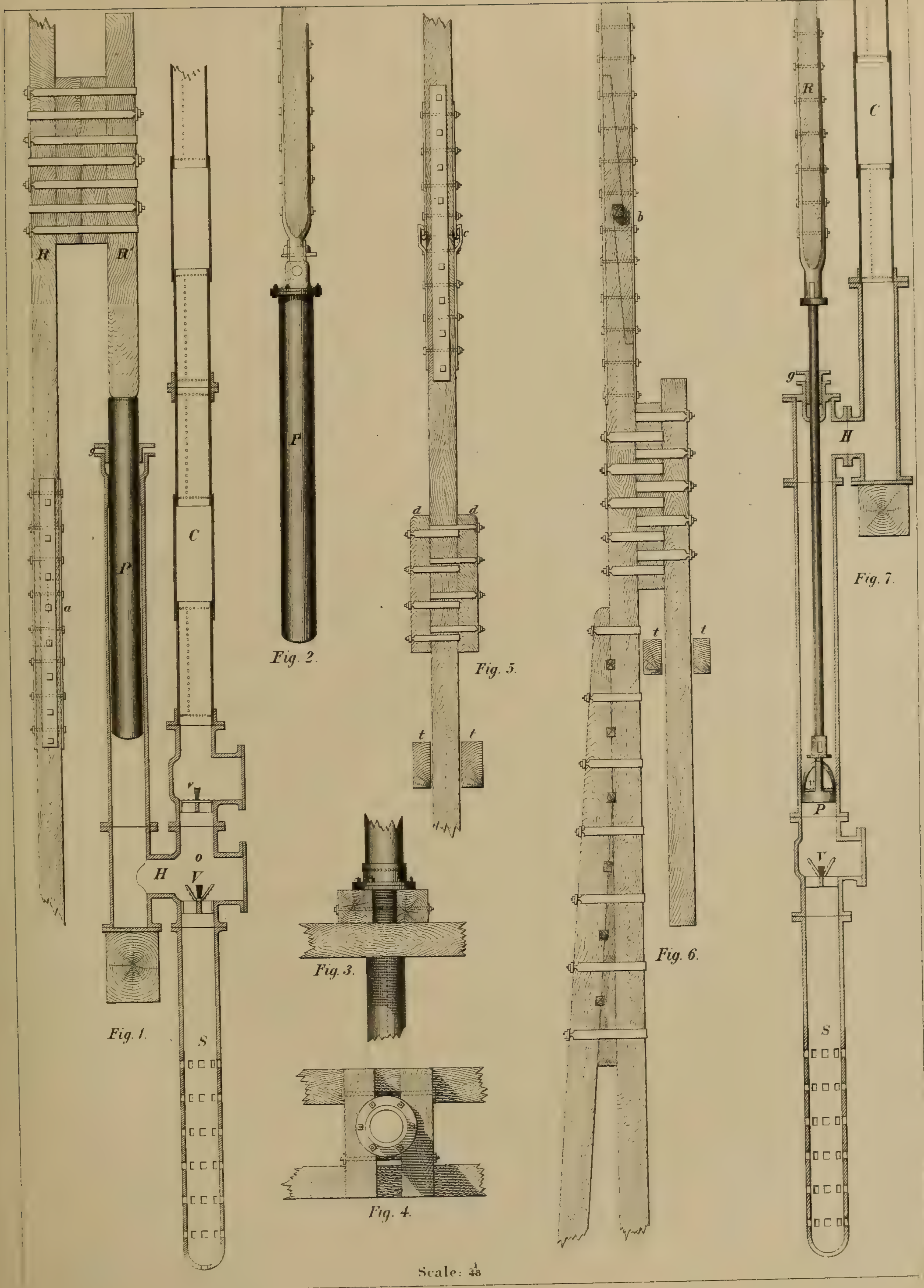



Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6. Fig. 7.

Scale: $\frac{1}{48}$

The pipe or column in which the water is raised above the piston is sometimes placed upon and directly over the cylinder, in which case the rod to which the piston is attached passes up through it and is connected above with the motive power; but commonly the pipe, or column of elevation, is fixed at one side and connected by a short horizontal or curved piece, *H*, with the cylinder, the top of which is then fitted with a stuffing-box, *g*. The piston-rod passes through the latter and is then connected with the main pump-rod, *R*, working in the shaft, from which it receives its motion.

The column may be of any desired height to which the strength of the material is adapted. As the lifting pump is generally only employed in the Comstock mines at the bottom of the shaft to raise the water to the force-pump above, the height of its column varies according to circumstances. In shafts where sinking is in progress the column of the lifting pump is constantly being extended as the shaft deepens, until a sufficient depth, 200 feet or more, has been attained for the convenient establishment of a force-pump, when the lifting pump is detached from the column, the force-pump put in its place at a suitable distance above the bottom, and the lifting pump again employed for sinking deeper with a short but gradually extending column.

*The Force-Pump or Plunger-Pump*, Fig. 1, Plate IX, forces the water upward in its column of elevation by the descent of the piston or plunger. This pump consists of a cast-iron cylinder or "plunger-case" usually 10 or 12 feet long and from 8 to 12 inches in diameter, in which a solid cylindrical piston, *P*, nearly as long as the cylinder, is caused to play with an upward and downward motion; the piston passes through a stuffing box, *g*, at the top of the cylinder, and is then connected with the pump-rod, *R′*, that gives it motion. Below the cylinder is a side or branch pipe, *H*, connecting the cylinder with a valve-chamber, *o*, and the column of elevation, *C*. The valve, *V*, in the chamber, *o*, retains the water drawn through it from the wind-bore or suction pipe *S*, which is immersed in the cistern. The valve, *v*, at the bottom of the column of elevation, *C*, opens for the passage of the water into the column and closes to retain it there. When the piston ascends, the valve, *V*, opens and the space in the cylinder, below the piston, fills with water; when the piston descends, the valve, *V*, closes, the valve, *v*, opens, and the column of water is forced upward to the point of discharge at any desired height.

The piston or plunger of the force-pump is a smoothly-turned cylinder 8 to 12 inches in diameter and 10 or 12 feet long. It is cast hollow, of iron about one inch in thickness. In order to attach it to the pump-rod, by which it is set in motion, a suitable stick of timber, considerably longer than the piston, is made to fit snugly into the inside of the cylinder or hollow piston, entirely occupying the interior space; being driven tightly in it is wedged at the bottom. The top, projecting above the end of the cylinder, is then attached to the main pump-rod, *R*, in manner shown in the figure.

Another method, used at the Savage, Fig. 2, Plate IX, is to have the plunger cast with a stout flange at the upper end, by means of which a head of cast iron is bolted to it, carrying two uprights with a stout iron pin, as shown in the drawing. To the end of the pump-rod is securely attached an iron stub-end, which is furnished with a strap, boxes, gib and key, forming a connecting link such as is commonly used in attaching the connecting rod of an engine to the crank pin. By means of this link the pump-rod is attached to the pin in the head that is bolted to the plunger, as just described.

The plunger-case and valve-chambers rest upon stout timbers, which are firmly established in the shaft in the most substantial manner. The column rests upon the valve-chamber, and is itself further supported by timbers fixed at intervals in the shaft and so arranged as to embrace the pipe directly under the flanges by which the sections of the column are joined together, and furnish a bearing for these to rest upon. This is illustrated by Figs. 3 and 4, Plate IX. The pump-column, generally used at the more important pumping works on the Comstock, is a pipe having a diameter of 12 or 14 inches. It is composed of sections about 10 feet long. The sections are made of wrought iron or boiler-plate, usually $\frac{3}{16}$ of an inch thick, strongly riveted together in cylindrical form. The plate employed is little more than 3 feet wide, so that three cylindrical pieces riveted together form a section of the column. At each end of each section a stout flange of cast iron, as shown in Fig. 3, Plate IX, is riveted to the plate, by which means the sections are connected. In other mining regions the pump-column is usually formed of cast pipe. On the Pacific coast the pipe, made as above described, is preferred on account of its comparatively less weight, a consideration of much importance where freights are so high.

It will be seen from the foregoing that the force-pump performs its work

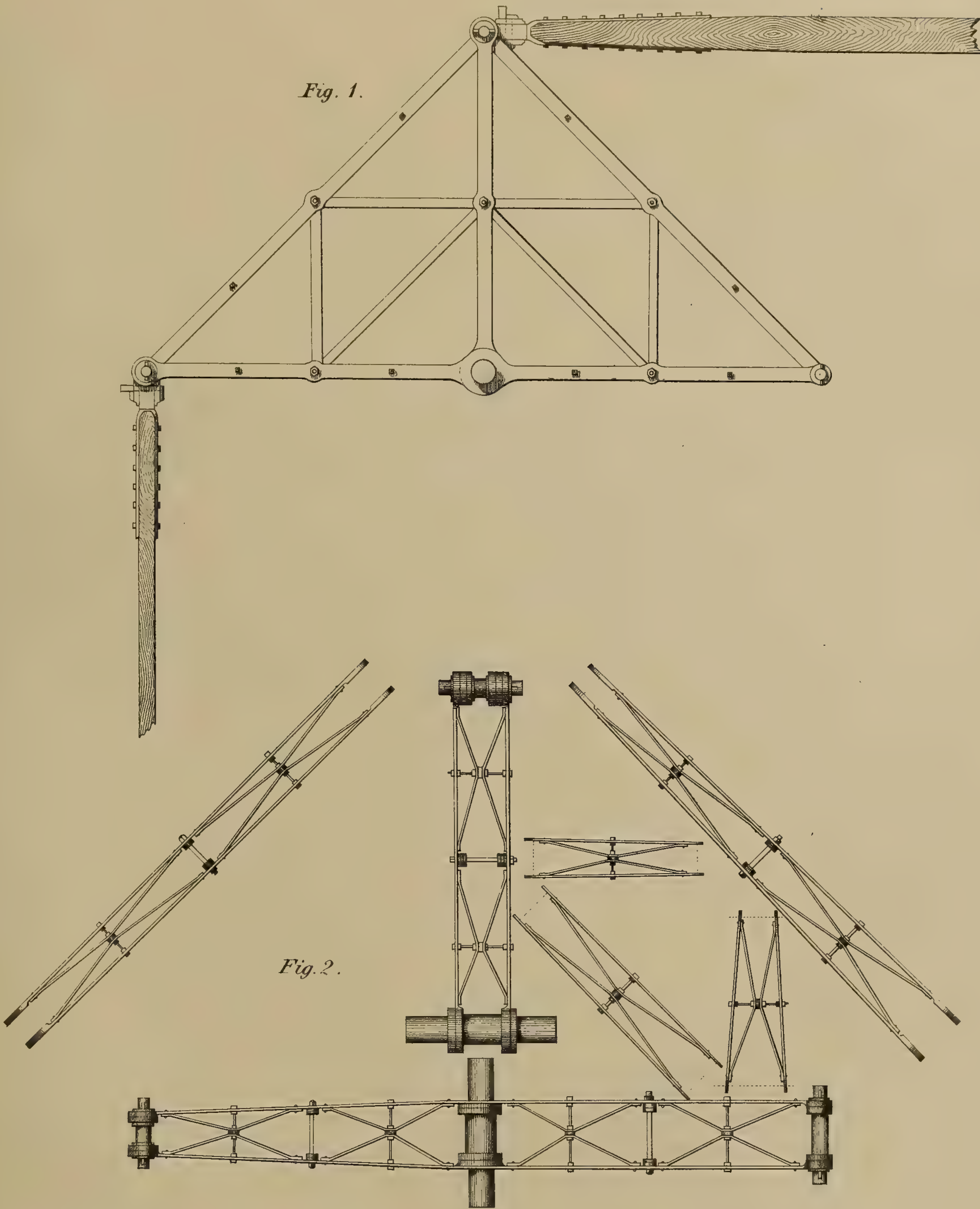
of raising the water on the downward stroke of the piston, while the lifting pump does its duty on the upward stroke. The force-pumps need to be very firmly set, and are therefore only employed where they can be permanently and solidly established in a position easily accessible for repair and not very liable to be submerged. The lifting pumps are well adapted to work in the bottom of the shaft, their method of construction and operation fitting them to draw water from the very bottom of the shaft without the use of a cistern, and to be extended, foot by foot, as the sinking proceeds; not requiring to be placed with so much care as the plunger-pumps, and having also the advantage of being operated as well even when the water rises above them in the shaft.

In order to extend the pump in depth as the sinking proceeds, the working parts of the pump, namely, the suction-pipe and working barrel, being suspended by heavy chains to a winch or windlass fixed at the station above, are detached, with the connecting pipe, from the bottom of the column, and lowered 10 or 12 feet, sufficiently to allow of introducing another length of pipe under the column, already in place; this additional length having been attached to the column, the working parts are again connected with the column thus extended, and are continued in operation until the sinking has so far progressed as to require the addition of another length of pipe, when the above-described proceeding is repeated. In the Comstock mines the suction-pipe, dipping into the pool of water at the bottom of the shaft, is usually a stout hose pipe, of diameter equal to that of the short iron pipe below the working barrel, to which it is closely fitted and attached. It is made of one or more thicknesses of canvas, rendered water-tight by applications of tar or other material of like properties. It has the advantage of flexibility and may be more easily protected against injury during blasting than iron pipes, commonly used elsewhere. The lifting pump discharges into a cistern from which the force-pump takes its supply to be raised to the surface or to the next cistern above.

The motion of the piston, or plunger, in its cylinder is imparted to it by the pump-rod, a continuous piece of timber, which is suspended in the shaft alongside of the column, extending from the surface to the bottom of the mine, and to which the plungers are attached. The pump-rod is composed

of timbers 8, 10, or 12 inches square, joined to each other so as to form a continuous piece. The method of joining the sections composing the rod varies in different mines. In the Savage mine the rod is of pine, 12 inches square, each section being 30 feet long, The sections are joined by a simple splice, as shown at *a* in Fig. 1, Plate IX, and strapped on four sides with iron plates 12 feet long, 6 inches wide, and ½ inch thick, securely bolted together by bolts 1 inch in diameter. In other mines the sections of the rod are joined in a more complicated manner by a beveled splice and key, as shown at *b* in Fig. 6, Plate IX, and strapped in manner similar to that just referred to. In the Gould and Curry, Ophir, and others, the square ends of the sections are brought together without any splice whatever, and joined simply by means of the iron straps. In the Ophir the straps on two sides of the rod are formed as shown in Fig. 5, Plate IX, so that a key can be inserted at *c*. When these keys are driven in as tightly as possible, so as to bring the two ends of the timber closely together and so prevent any lost motion in the action of the rod, the two straps for the remaining two sides are put on and bolted together.

The motion of the rod is communicated to it from the engine by means of an oscillating "bob," established at the surface. The construction of a bob may be seen by reference to the figures on Plate X, which give the details of one used at the Gould and Curry mine. In the case illustrated the bob is made entirely of wrought-iron. Its method of operation is shown in the drawing on Plate XVI. The pumping engine drives, by means of the pinion, the pump wheel, to one side of which is attached, by means of a wrist-pin, one end of the pitman. As the wheel is set in revolution by the engine, the pitman receives a reciprocating motion, the length of stroke being determined by the distance of the wrist-pin from the center of the wheel. The other end of the pitman being connected to the king-post of the bob, causes that to oscillate, giving to the pump-rod in the shaft an upward and downward motion. The upper section of the rod is usually connected to the nose of the bob and the next lower section of the rod by means of a strap and boxes, so as to allow for the vibration caused by the angular motion of the bob; deeper in the shaft the sections are joined together as already shown, forming one continuous piece, which is guided in its movement by




Scale: $\frac{1}{64}$.

timbers, *t*, *t*, Fig. 5, Plate IX, fixed across the shaft at right angles so as to confine the rod on four sides and prevent vibration.

The timbers, *t*, *t*, Fig. 5, which are placed in the shaft at frequent intervals, also serve to prevent the rod from falling far, in case of fracture, by furnishing support to the catching pieces, *d*, *d*, which are attached to the rod for this purpose. These catching pieces are attached by iron clamps or straps, which are sometimes applied as shown in Fig. 5, where each clamp embraces the main rod and only one side-piece; or sometimes, as shown in the attachment of the plunger to the main rod in Fig. 1, where each clamp embraces the rod and both side-pieces. The arrangement in Fig. 5 is preferred by some, as each side-piece is thus attached independently of the other.

The length of stroke, or upward and downward movement of the rod, varies from 3 or 4 to 7 or 8 feet, and the number of strokes per minute varies from 3 or 4 to 10 or 12, according to the size and character of the pump and the duty required of it. The pump-rod being continuous, where several pumps are employed in a series, one above the other, as is the case in deep shafts, the plungers or pistons of all the pumps so placed are attached to the same rod in manner shown in Fig. 1, Plate IX.

The weight of the rod in most cases considerably exceeds that of the water to be raised, so that, descending by its own gravity, it exerts sufficient force to raise the column of water without requiring additional power from the engine. For the next stroke, however, the engine must lift the total weight of the rod to the required height.

In order to prevent the too rapid descent of the rod and to equalize the work of the engine on either stroke, counter-weights are attached to the opposite end of the oscillating bob at the surface. The descending rod must raise the counter-weight, which, on the reverse stroke, assists in lifting the rod. In deep shafts, as the rod increases in length and weight, additional counter-weights are applied by establishing at various stations in the shaft similar oscillating bobs, attached at one end to the rod and bearing at the other end a heavily weighted box.

Nearly all the deep-working mines on the Comstock are now supplied with large pumps, similar in general character and method of arrangement to such as have just been described, and varying from 10 to 14 inches in diam-

eter. In the Savage mine the pumps are 10 and 12 inches in diameter. The water is raised from the bottom of the shaft, about 1,000 feet deep, to an adit-level, which is about 120 feet below the surface, where it is discharged. For this purpose two plunger or force-pumps are in use, one above the other, each raising the water about 300 feet. Below the lower one of these pumps a lifting pump is employed, which is extended in depth as the sinking proceeds. The latter pump lifts the water from the bottom to a cistern above in which the windbore of the lower plunger or force-pump is placed; thence it is forced by the last-named pump to a cistern 300 feet higher, and thence again by the upper force-pump to the adit-level, where it is discharged.

The ordinary working capacity of the pumps thus employed in the deep mines is about 250 gallons per minute, though when required they can be worked up to a considerably higher duty than that. It is not often that they are required to perform their full duty. It is the liability to which the mines on the Comstock are subject, of encountering at any time a great influx of water, that makes the provision of large pumps necessary.

The clay-seams of the vein appear to act as dams, effectually retaining the water in certain places, and preventing the regular drainage of the ground.

Thus in the Yellow Jacket, the so-called North Mine being idle, was filled with water during one or two years, which was not drained off by the South Mine, which was much deeper, even when the drift from the latter, on a level 100 or 200 feet lower, had been carried north so far as to be directly under the water of the North Mine. Similar cases are reported in other parts of the lode. It is said that years ago the Gould and Curry mine was much deeper than the Savage without draining it.

The Ophir company, in sinking their deep shaft during the winter of 1867 and 1868, met with large quantities of water, to remove which pumps of large capacity were provided and steadily employed until, on reaching a depth of several hundred feet, the sources of the water appeared to be exhausted and the influx ceased almost entirely. The work remained exceedingly dry until, in the autumn of 1869, a new body of water was tapped by the drift on the 700-foot level.

In some of the mines where sinking is in progress the pumps must be

steadily employed, even on comparatively little water, but working on short stroke and at low speed. In others they are idle during a great part of the day, and in some, among them some of the deepest works on the lode, the ground has been almost entirely without water.

VENTILATION.—During the earlier years of work on the Comstock lode little or no difficulty was experienced in effecting free ventilation of the mines, the underground works, even to considerable depths, being in communication with the surface either by adits or connected shafts in such manner as to insure an easy circulation of air.

As the depth increased and work had to be done at points not reached by the ordinary circulating currents of air in the mine, various simple and well-known means were employed to supply fresh air to the laborers. One of the simplest and most efficient appliances for that purpose formerly used in the Gould and Curry was the water blast, consisting of a wooden box-pipe, *P*, Fig. 4, Plate VI, standing in the shaft some 200 feet high, and connected at the bottom with an air pipe, *A*. In the case illustrated, the standing pipe extended from the fourth station down to the sixth, at which point an exploring drift was being carried eastward several hundred feet. The object of the blast was to supply air to the laborers in the end of this drift. The top of the box pipe, *P*, is open, and a finely divided stream or shower of water being caused to fall into the box carries down with it a volume of air. The bottom of the pipe, *P*, dips into a box, *B*, 2 or 3 feet long and 15 inches deep, in which the water is allowed to stand above the bottom of the pipe, and from which the excess escapes, through a sliding gate or valve, *v*. Connected with the water pipe just above the box, *B*, is the air pipe, *A*, leading to the point to which fresh air is to be forced. The air coming down the standing pipe, *P*, with the water, and having no other means of escape, is driven along the horizontal air pipe, *A*, and delivered at the desired point.

Latterly the deeper mines have found the lack of good air and the greatly increased heat sources of much trouble, and some of them have been forced to resort to more costly means of ventilation. For this purpose the method generally in use at present is that of forcing air down the mine and into the several levels or tunnels, where it is most needed, by means of a Root's Blower. This machine, well known for purposes of the kind, has been found

very efficient and has given much satisfaction to the mining companies that employ it on the Comstock. It is made of various sizes. At the Ophir works a No. 5 machine is used, the drum being 4 feet long. It is driven by a small engine provided especially for the purpose, but capable of doing additional work. The machine is calculated to run at 300 revolutions per minute, but running at 130 revolutions fully performs the present required duty, forcing the air down 700 feet in the shaft and thence to the end of the drift, several hundred feet more.

For conveying the air down the shaft and along the drift a square, wooden box-pipe is used. When these blowers were first introduced the conveying pipes were made of galvanized iron, but this material was not proof against the corroding influences of the water in the shafts, and very soon became useless in that part of the work, though better adapted to the drier levels. Air-boxes of common pine wood were used next, but the tendency of this wood to split and crack caused them to leak very badly. The best and most satisfactory material now in use for this purpose is the redwood of California, which seems to be less affected than any other by the changes of temperature and different degrees of moisture in the mine. The air-box or conveying-pipe is made of dressed lumber 1½ inch thick, and is about 12 inches square in horizontal section. The four sides of the box are tightly joined together with a tongue and groove, as shown in Fig. 3, Plate VI, at *a*, and the ends of the sections of pipe are connected by letting the lower end of the upper section into the upper end of the lower section as shown in same figure at *b*. An iron band is put round this joint which is well packed and then covered with a thick coat of paint. The pipe is supported in the shaft by clamps, *c*, *c*, Fig. 2, which secure it to the timber-sets. It is fixed snugly in the corner, usually of the pump-compartment, the clamps securing it as shown in the figure. The cost of this air-pipe, finished and placed in the shaft, is about $1 50 per foot. The cost of the blower of the size used at the Ophir (the largest made) is $700. It may, of course, be driven by the same power that is employed for hoisting or pumping, but as the work is continuous and cannot be interrupted while men are working in the mine, a small engine, devoted exclusively to this duty, is preferred and generally provided by the Comstock mines.

The method of drawing the foul or heated air from the mine by means of the blower and allowing fresh air to take its place by entering the shaft, a plan used elsewhere and much preferred by some, has not been tried on the Comstock, so far as the writer is informed. If readily practicable it would probably furnish better and cooler air throughout the mine generally than is furnished by the means now in use. In the Crown Point mine the 1,100-foot level, at the time of the writer's last visit, was insufferably hot throughout almost its entire length ; the air being cool and fresh only at the extreme end of the pipe and becoming heated immediately after its exit.

Hoisting and Pumping Works.—The hoisting and pumping works on the Comstock lode are among the best of their kind in the country. As most of the claims located on the vein are short in extent, few of the companies have more than one working shaft, and in some cases, as in that of the Empire-Imperial and neighboring short claims, a number of companies have combined in sinking one shaft for their common use. The principal shafts of the leading companies of the present day are generally established on a liberal scale, designed for permanent and deep workings and furnished with pumping and hoisting machinery of the most substantial and effective sort. These surface works are located directly at the mouth of the shaft, and are usually well inclosed by large and conveniently arranged buildings, connected with which are the various shops for all necessary auxiliary work, such as carpentry, smithwork, and general repair.

The engines employed for hoisting and pumping are, in most cases, horizontal, non-condensing engines. Sometimes one engine performs the whole duty of pumping and hoisting, but in the larger mines, it is customary to provide one engine for pumping only, and one or more for hoisting rock and ore.

In hoisting apparatus, the winding reels or drums are operated either by cog or friction-gearing. The latter was much used a few years ago, but as the depth of the mines has increased it has been abandoned by some and replaced by cog-gearing, which is thought safer and more effective for deep works.

The kind of friction-gear formerly in general use is that known as the V-wheel and pinion, the construction of which is shown, in detail, in Fig. 2, Plate

XIV. The face of the wheel, usually about 8 or 10 inches wide, is formed with V-shaped grooves, two or three in number, which extend, continuously, entirely around the periphery; the face of the pinion is of corresponding form, but it is so placed with regard to the wheel that the projecting ribs, between the grooves, fit into the recesses in the face of the wheel. The pinion is keyed to the engine shaft and may be set in revolution by it. The wheel, being so placed that its face may be brought into contact with the face of the pinion, is caused to revolve by friction, if the two surfaces of wheel and pinion be forcibly pressed together.

The friction-wheel forms one end of, or is attached to, the drum on which the rope or cable is wound. In Fig. 2, Plate XIV, the wheel, *W*, is cast in one piece, and the drum or spool consists of two flanges, *F*, *F'*, which are connected together by plates of iron, bolted as shown in the drawing. The spool is joined to the friction-wheel by bolts, *b*, *b*, passing through the flange, *F'*. To the opposite flange, *F*, is bolted a broad rim, *R*, to which is applied a brake-strap. This strap is usually a band of iron, 4 or 5 inches wide, which encircles the rim, *R*, of the spool, and may be made to grasp it tightly, thus arresting the movement of the same. There are various methods of applying the brake to the rim. One of them is shown in Fig. 3, Plate XIV. L is a long lever, broken off in the drawing. The strap shown in Fig. 3 is for a smaller drum than that represented by Fig. 2; but the method of application may be the same.

The general method of arrangement of this kind of machinery is illustrated on Plate XI. Fig. 1 is a side elevation, and Fig. 2 a plan of the hoisting gear In Fig. 2 the relative position of the engine to the winding drums is shown. In the case illustrated there are two drums, each of which is independent of the other. The friction-pinions, *P*, are keyed to the engine shaft, S, and are caused to revolve by it. Each friction-wheel, *W*, forms a part of a winding drum, *D*, which is supported in pillow-blocks, *B*, that may slide backward and forward on the bed-plate beneath them. They move horizontally between guides or flanges, which prevent any upward motion. The sliding movement is imparted to the pillow-blocks by means of the arms, *a*, connecting them with a short lever at *b*, which is keyed to a rock-shaft, *c*. If this rock-shaft be slightly turned toward the drum the arms are advanced and the fric-

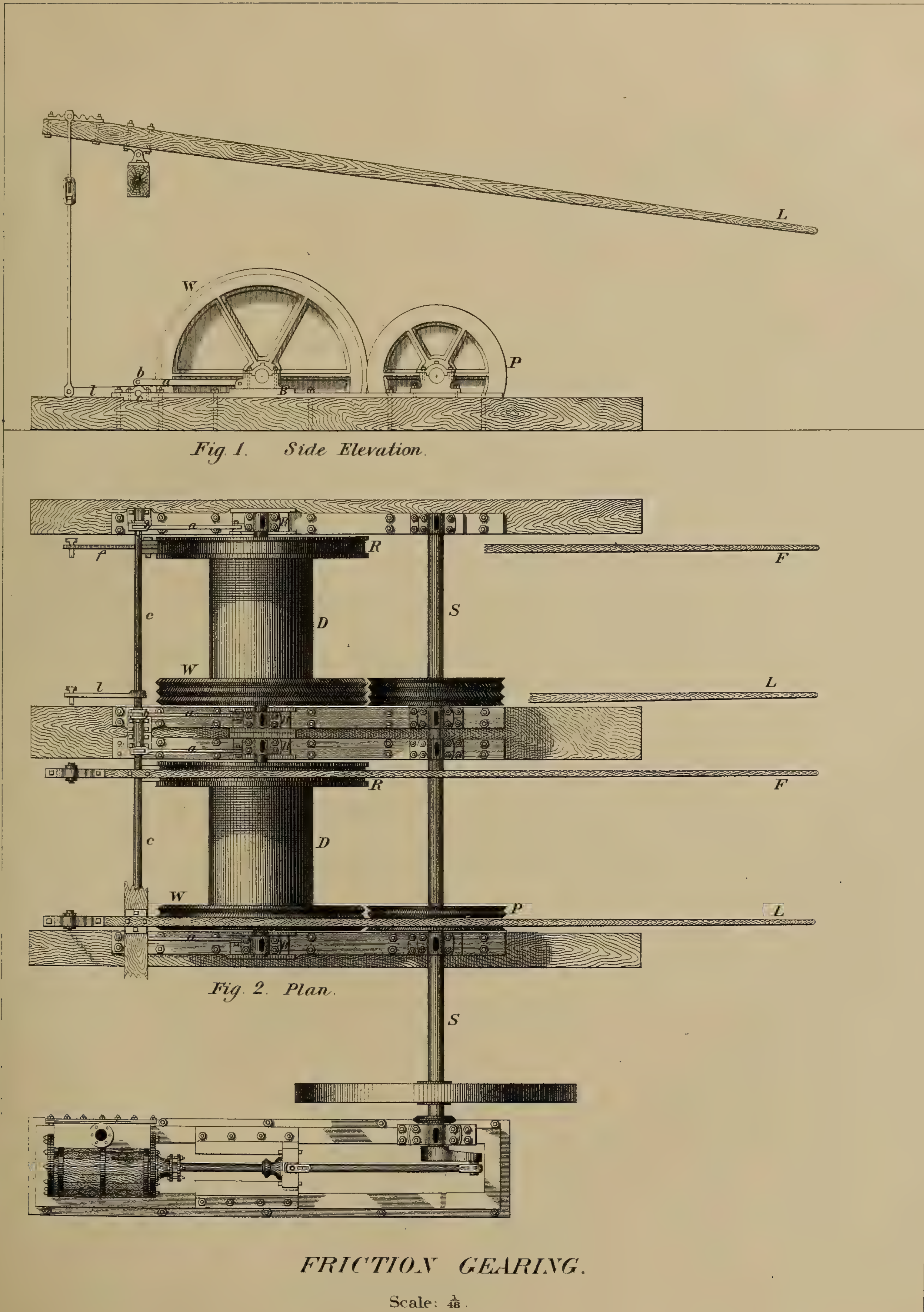



Fig. 1. Side Elevation.

Fig. 2. Plan.

FRICTION GEARING.

Scale: $\frac{1}{48}$.

tion-wheel brought into contact with the pinion. If it be turned from the drum the wheel is removed from such contact and may be held by a brake. The desired motion is given to the rock-shaft, *c*, by the short lever, *l*, and the long arm *L*, which is at the hand of the attendant. On the opposite end of each drum is a rim, *R*, for the brake-strap. The brake is controlled by the short lever *f*, and the arm *F*, which, like the arm *L*, is within easy reach of the operator.

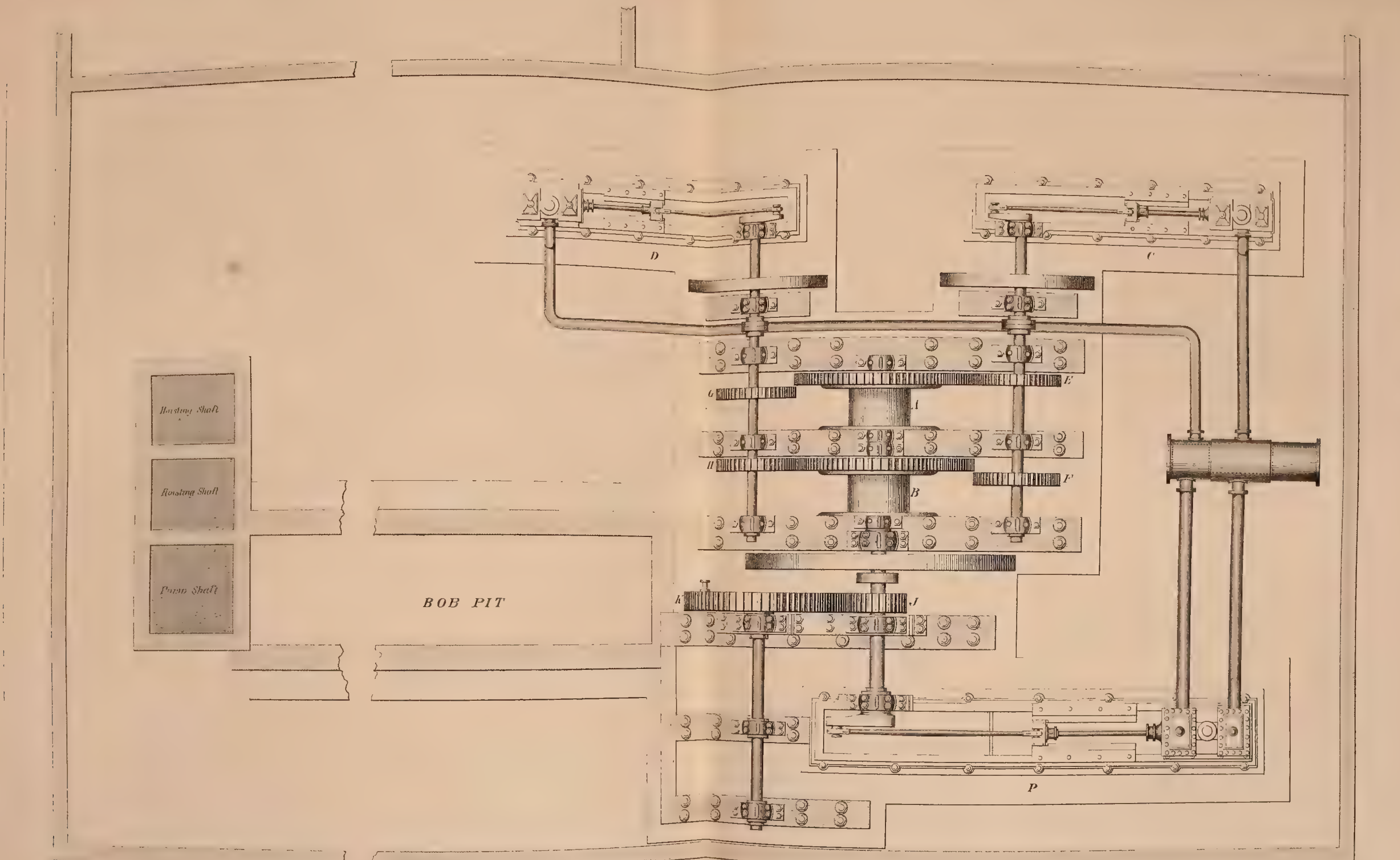
This method of operation has some advantages in the simplicity with which the machinery is controlled and economy in the labor employed. The engine runs steadily in one direction, and, not needing to be reversed, requires but little attention. It may also be applied to other continuous work, such as pumping, the driving of air-blowers or other machinery, which cannot be done when the engine is stopped and reversed at short intervals.

One man, in small mines or where the quantity of rock to be hoisted is not very great, may attend to the whole work of controlling the engine and disposing of the material hoisted. The attendant stands at the mouth of the mine-shaft. He has, at one hand, a lever to set the winding drum in motion; at the other a lever operating the brake on the drum, and, within easy reach, the means of opening or closing the throttle-valve of the engine, so that he may diminish or increase the quantity of steam, according to circumstances. On the arrival of the loaded car at the surface the same man may attend to its discharge and send it below again. One objection to this method is, that with very heavy loads the wheels are liable to slip against each other; and another, that it is not readily practicable to lower a loaded cage into the mine under the control of steam, making it therefore necessary to depend entirely on the brake for that purpose. This is particularly objectionable in deep mines where the weight of the long cable is itself very considerable. In the Comstock mines the men employed under ground are lowered into the mine on the cages; and it is always deemed safer to do this under the control of steam rather than by the brake alone.

Where cog-gearing is employed the motion of the engine is imparted to the shaft carrying the winding drums or reels by toothed wheel and pinion. There are various ways of applying this kind of gearing. In some cases, as at the Savage, the spur-wheel and winding reel are keyed to the same shaft

and driven by a pinion which is keyed to the engine-shaft, so that the reel must always have a motion corresponding to that of the engine, and cannot, as is practicable in some other methods of arrangement, be reversed, for lowering the cage, unless the engine be reversed also. In the Savage works, shown on Plate XV, there is a separate engine and independent winding gear for each hoisting compartment of the mine-shaft; and so arranged that each engine is connected with but one reel and cannot work either of the others. In this arrangement the practice, sometimes desirable, of hoisting one cage as the other descends, in such manner as to allow the descending cage and rope to counterbalance the ascending, is impossible.

Another method, similar to the above in some respects, but possessing important modifications, is that which is in use at the Crown Point works, shown on Plate XII. In this case there are two winding spools or drums, *A* and *B*, one for each hoisting compartment. There are also two hoisting engines, *C* and *D*, each of which, under ordinary circumstances, is used for a single compartment. Each spool, with its spur-wheel, is keyed to a spool-shaft and driven by a pinion, which is keyed to the engine-shaft The engine must therefore be reversed, as in the case of the Savage, in order to reverse the motion of the spool; but the engine-shaft of either engine is long enough to control both spools and each shaft is provided with two pinions, one for each spool. Under ordinary circumstances, the machinery is arranged as shown in the drawing. The engine on the right, *C*, drives the spool *A*, nearest to it, by the pinion *E*, the pinion *F* for the remote spool *B*, being thrown out of gear; while the engine on the left, *D*, drives the remote spool *B*, by the pinion *H*, the pinion *G*, for the nearer spool *A*, being thrown out of gear. In case of accident to one engine, the other can work either spool; or, by throwing out of gear both pinions of one engine, and putting in gear both pinions of the other engine, both spools may be driven at the same moment, one hoisting and the other lowering a cage. In this case, of course, the two ropes or cables must be wound upon the spools in opposite directions. There are no brakes on these spools; but one is applied to the fly-wheel of each engine. The pumping engine, *P*, in the case illustrated, has no connection with the hoisting gear, and is devoted exclusively to driving the pump by means of the pinion, *J*, and wheel, *K*, as shown in the draw-




CROWN POINT HOISTING WORKS.

Scale $\frac{1}{60}$

ing; nor can either hoisting engine be applied to the pump, in the arrangement indicated.

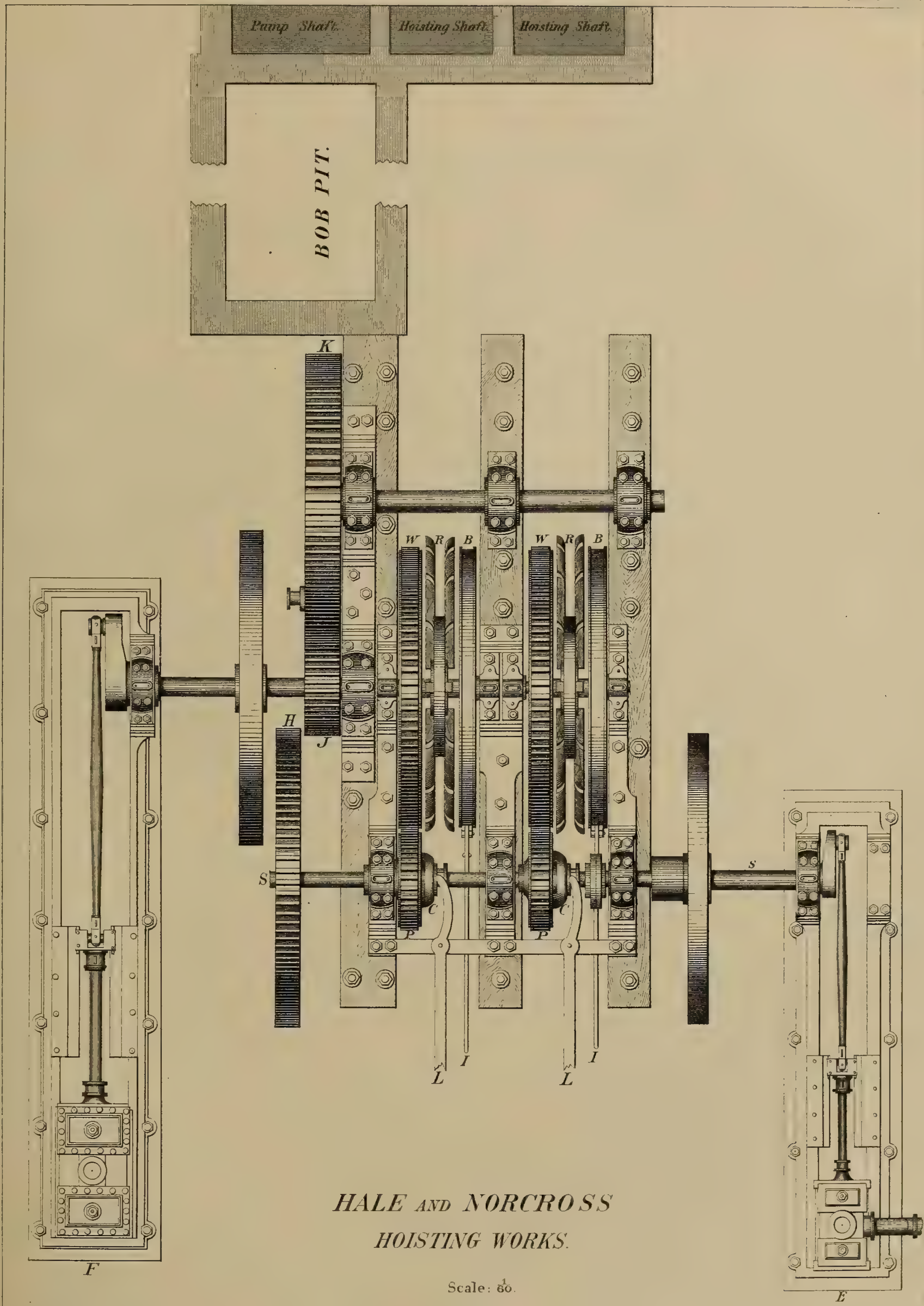
Another method of arrangement is one by which the motion of the hoisting reel may be reversed without reversing or arresting the motion of the engine.

In some cases where this method is in use, as at the Ophir and Empire-Imperial works, the winding reels are supported upon the reel-shaft, not keyed to it, but turning freely upon it in either direction. The reel-shaft receives its motion from the engine by means of a pinion and spur-wheel, but may turn freely without imparting motion to the reels except when the latter condition is desired. In such case a reel is caused to revolve with the shaft, by throwing into contact with it a clutch that slides upon a feather on the shaft. As the clutch always has the motion of the shaft, it causes the reel to turn with it, while in contact, and on being withdrawn from contact the reel is free to be reversed, for lowering the cage, while the motion of the engine shaft is continuous. Such reels are cast with a flange or rim for a brake-strap, by which the reverse motion is controlled. This method of arrangement requires but one hoisting engine for two or more reels. The latter are all upon the same reel-shaft, but work independently of each other, and as the reel-shaft moves continuously in one direction the engine may be applied to other work, such as pumping, or driving other machinery that requires continuous motion. If desired, however, two reels may be permanently clutched to the shaft and revolve with it, one winding and raising a loaded cage from the mine, while the other is unwinding and lowering an empty cage, gaining in this case the advantage of the weight of the descending cage and rope. In the last case, the engine must, of course, be reversed for each operation of hoisting and lowering; and the ropes must be wound upon the reels in opposite directions.

In the Hale and Norcross works, a plan of which is shown on Plate XIII, this method is in use, with some modifications, that appear in the drawing. In this case each of the two reels, *R*, *R*, is keyed to a separate reel-shaft with a spur-wheel *W*, and brake-rim, *B*. The reels are entirely independent of each other. There are two pinions, *P*, *P*, one for each reel, on the engine-shaft, *S*. These pinions are not keyed to the engine-shaft but turn freely in

either direction, independently of the motion of the shaft. They may be made to revolve with the shaft by the clutches, *C*, which, being fixed to the shaft by a feather, may slide toward or from the pinions. If the clutch, *C*, be moved into gear with the pinion, *P*, the latter receives the motion of the engine-shaft and transmits it to the reel; if the clutch be withdrawn from its contact with the pinion, the reel may turn in the opposite direction while the motion of the engine is uninterrupted. The reel may therefore be moved by the engine for hoisting, and, when reversed for lowering, may be controlled by the brake. The clutches are moved in and out of gear by the levers *L*, *L*; the brakes are applied by similar levers *I*, *I*. If it be desired to lower a cage under control of steam, as is usually the case when men are descending, it is only necessary to leave the clutch in gear and reverse the engine. It will be seen that both reels may hoist at the same moment; or by fixing both clutches permanently in gear and reversing the engine for each operation, one reel may hoist while the other lowers, using the descending cage as a counter-weight for the ascending one, as already described. It will also be seen that by this arrangement, the single engine, *E*, may not only do all the hoisting, but drive the pump also. The engine-shaft extends beyond the reels and, by the wheel *H*, if the latter be moved into gear with the pinion, *J*, of the pump wheel, *K*, may set that in motion. The pumping engine, *F*, is commonly used for this purpose, but, in case of necessity, its work may be done by the hoisting engine, *E*. Hoisting may also be performed by the pumping engine, if the wheel, *H*, be put in gear with the pinion, *J*. Thus, if desired, either engine may serve as a substitute for the other.

The cables commonly employed in the hoisting works of the Comstock mines are either flat ropes of steel or iron wire, or heavy, round hemp ropes. Chain is used very rarely, if at all. Flat ropes are generally preferred, especially for great depths, because they possess greater strength in proportion to their size, winding themselves compactly upon a reel and withstanding, better than the hemp, the wear and tear of the work. They are usually from 3½ to 5 inches wide, and vary in thickness according to the character of the material of which they are made. If of iron wire they are from ½-inch to ¾-inch thick; if of steel they are usually ⅝-inch in thickness. The latter is preferred on account of its lighter weight, less bulk, (an important




HALE AND NORCROSS
HOISTING WORKS.

Scale: $\frac{1}{60}$.

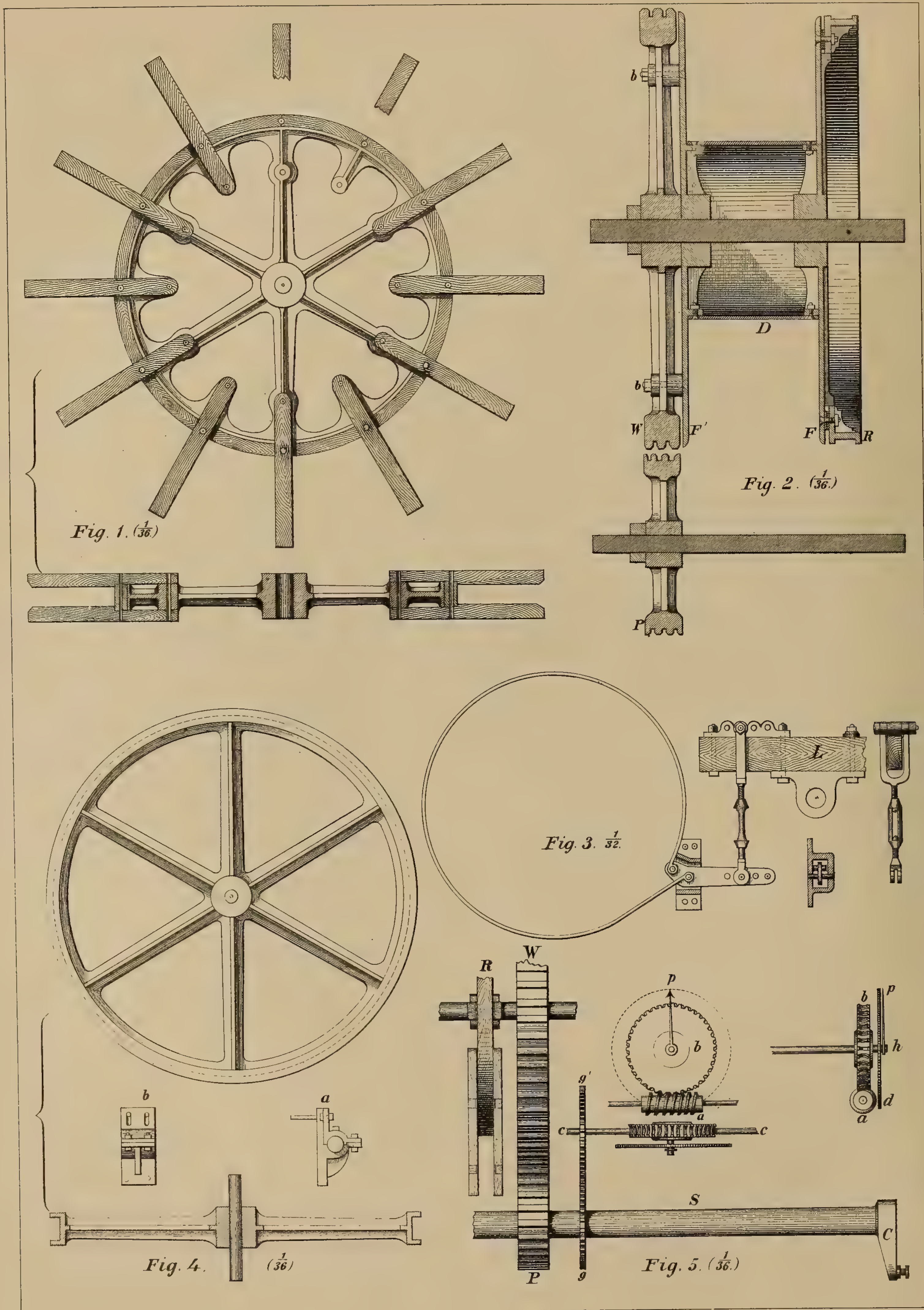



Fig. 1. (1/36.)

Fig. 2. (1/36.)

Fig. 3. 1/32.

Fig. 4. (1/36)

Fig. 5. (1/36.)

consideration when the space allowed for winding reels is limited) and greater strength.

Flat ropes are wound on narrow reels, the width of which is but very little greater than that of the rope. The latter therefore winds upon itself at each revolution of the reel. A common form of the reel used in this district is shown in Fig. 1, Plate XIV. It is a central wheel of cast iron, 6 or 8 feet in diameter, to which are bolted a number of wooden arms, making the total diameter about 12 feet. They are sometimes cast with a rim for the application of a brake.

For hemp ropes, spools or drums are used, one form of which, combined with a friction wheel, is shown in Fig. 2, Plate XIV; and another form, in the plan of the Crown Point hoisting works, on Plate XII.

The rope or cable passes from the reel or spool, over a sheave, which is supported directly above the hoisting shaft, and thence downward into the mine, its end being attached to the cage or bucket.

The sheaves are made of wood or iron, and of various dimensions. Those of large diameter, 8 or 10 feet, are preferred, as they cause less wear and tear to the fiber of the cable. A sheave of common form is shown in Fig. 4, Plate XIV. It is made of cast iron. It is supported in a gallows-frame, which is built at the mouth of the shaft, and so placed with reference to it, that the rope, passing over the sheave, may be suspended over the middle of the compartment in which it is employed. A frame of this sort is shown on Plate XVI, representing the arrangement of the hoisting machinery of the Savage mine. In Fig. 4, *a* and *b*, Plate XIV, show the pillow-blocks in which the sheave is supported.

The following description of the Savage hoisting works may serve to illustrate some of the details referred to in the foregoing pages. They are well arranged and liberally provided with the necessary power and other facilities for extensive and permanent operations. The general arrangement of the works at the shaft is represented on Plate XV, which gives the ground-plan of the most essential parts of the establishment, showing the engine and boiler-rooms, the pumping and hoisting engines and their relative positions to the other pumping and winding apparatus, the shaft-landing

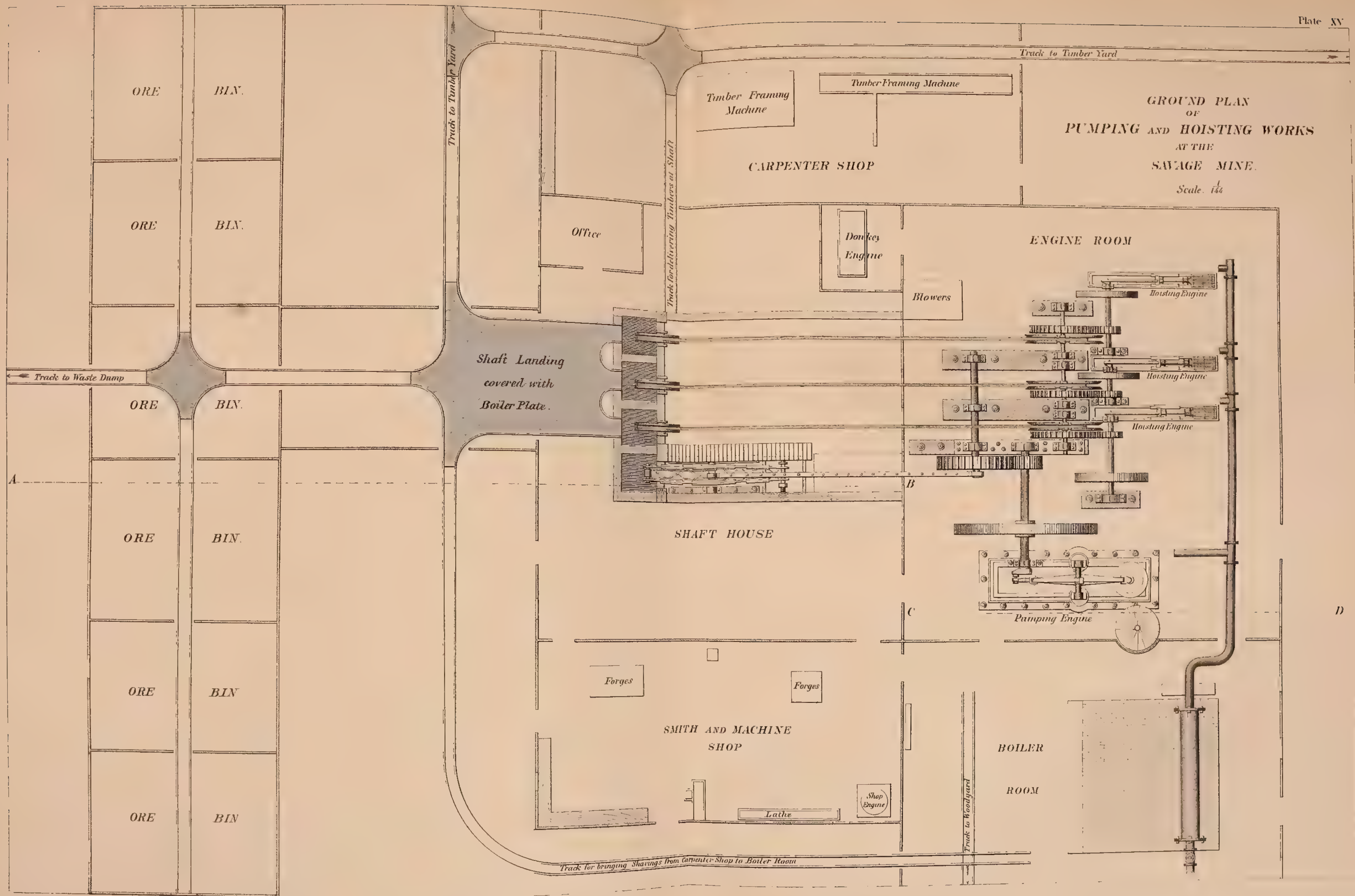
and ore-house, smith and carpenter-shops. The latter are not shown in their full dimensions. The ground adjacent to the establishment, not included within the limits of the drawing, is conveniently arranged for wood and timber yards, weighing houses near the ore-house, and all other desirable appurtenances for the prosecution of the business. Plate XVI gives a sectional view of parts of the same establishment, showing the manner in which the pumping engine transmits power, by means of the pump-wheel, pitman, and bob, to the pump rod in the shaft; also the arrangement of one of the hoisting engines with its winding reel, rope, sheave, and cage. The pumping engine of the Savage mine is one of the Corliss pattern; a beam engine with vertical cylinder, 26 inches in diameter and 6 feet in stroke, a very beautiful and efficient but costly machine. On the crank-shaft is a pinion, 3 feet in diameter, which drives the main wheel, 10 feet in diameter, carrying the pitman by which the balance-bob and the connected pump-rod are set in motion. The wheel and pinion have a 16-inch face. The former is constructed with mortise gearing, consisting of a cast-iron wheel, the periphery or face of which, instead of having iron teeth, as usual, consists of a stout rim provided with spaces into which wooden teeth are carefully fitted. The engine is usually run at 10 or 12 strokes per minute, though calculated to make 27 per minute. The pump-rod makes a stroke of 7 feet, under ordinary circumstances, about four times per minute, though capable of much higher duty, if required.

The bob is of wrought and cast iron combined. The pump-rod is made of pine, in sections 30 feet long and 12 inches square, joined together as already described. The weight of the rod, with its iron straps, is partly balanced by the counter-weight on the bob at the surface, besides which there are three balance bobs at stations below ground. The pumps have been already described. The plungers are 10 and 12 inches in diameter. The column of elevation is 14 inches.

There are three hoisting engines, one for each compartment of the shaft. They are 16-inch horizontal cylinders, having 36 inches length of stroke, and are fitted with slide valves and link motion.

Three boilers furnish steam to all these engines. They are set in the adjoining boiler-room, partly shown in the drawing. They are each 16 feet

Plate XV


GROUND PLAN
OF
PUMPING AND HOISTING WORKS
AT THE
SAVAGE MINE.
Scale. 1/144
Track to Timber Yard
Track to Timber Yard
Timber Framing Machine
Timber Framing Machine
CARPENTER SHOP
ORE
BIN.
Office
Track for delivering Timbers at Shaft
Donkey Engine
ENGINE ROOM
Blowers
Hoisting Engine
Hoisting Engine
Hoisting Engine
Shaft Landing covered with Boiler Plate.
Track to Waste Dump
A
B
C
D
SHAFT HOUSE
Pumping Engine
Forges
Forges
SMITH AND MACHINE SHOP
Lathe
Shop Engine
BOILER ROOM
Track to Woodyard
Track for bringing Shavings from Carpenter Shop to Boiler Room

long, 4 feet in diameter, containing 50 tubes of 3 inches diameter. They consume about 8 cords of wood per day.

The three hoisting engines stand side by side, and are so placed that the winding reel, operated by each engine, is directly opposite the compartment for which it is designed. Each engine, with its winding apparatus, is independent of the others.

The winding apparatus, connected with each engine, consists of a reel, similar in construction to that shown in Fig. 1, Plate XIV. The reel is keyed to a shaft 7 inches in diameter, which is driven by a spur-wheel 10 feet in diameter; the latter is moved by a geared pinion on the engine shaft. The relative diameters of the spur-wheel and pinion are as $3\frac{1}{2} : 1$.

The cable is made of steel wire. It is flat, $4\frac{1}{4}$ inches wide by $\frac{3}{8}$ of an inch thick. It is of the best English manufacture, and is said to withstand a breaking strain 30 per cent. greater than cables of iron wire, which are twice as thick. One great advantage of the steel over iron band is its slight thickness, which allows of winding a much greater length of band on a reel of given diameter, consequently reaching a greater depth without change of winding gear. The reels now in use have a capacity of 1,200 feet of rope.

The average speed of hoisting the cage in the shaft is about 400 feet per minute.

The engine driver, engaged in hoisting, stands by his machine, controlling the throttle-valve by one hand, the reversing-bar with the other, and a brake with one foot. The brake is applied to the fly-wheel of the engine, and is sufficiently powerful to hold a loaded cage. The winding apparatus being geared, and the spur-wheel keyed to its shaft, the engine is always reversed for lowering the cage, which operation may be managed by the brake on the fly-wheel, or controlled by a pressure of steam.

The position of the cage in the shaft, at any moment of its ascent or descent, is shown to the operator by an "indicator," connected with the winding machinery, and in full view of the engine driver.

The indicator used at the Savage mine consists of a circular plate or dial, about the center of which a pointer, like the finger of a clock, revolves, showing, by means of points marked upon the circumference, the position of the cage in the shaft. When the cage is at the surface the finger stands ver-

tically, marking on the circumference the starting or zero point. As the cage descends the finger turns on the dial, passing successively the points corresponding to the several stations or intermediate places in the shaft. The construction of this apparatus is illustrated by Fig. 5 on Plate XIV. *S* is the main engine-shaft, set in motion by the crank *C*. The pinion, *P*, drives the spur-wheel, *W*, by means of which the winding reel, *R*, is caused to revolve. The relations of the pinion to the spur-wheel being as 1 : $3\frac{1}{2}$, the winding reel, *R*, makes 100 revolutions for 350 of the engine-shaft. On the latter, near the pinion, *P*, is fixed a light gear-wheel, *g*, two feet in diameter, which drives, by means of a similar wheel, $g'$, the countershaft, *c*. This countershaft is provided with a worm, shown at *a* in elevation, above which is a worm-wheel, *b*. This is a disk, two feet in diameter, the face or periphery of which is cut to correspond with the worm *a*, and has 350 threads. As the countershaft, *c*, and worm, *a*, revolve with the same speed as that of the engine-shaft, *S*, the disk, *b*, is caused to make one complete revolution by 350 revolutions of the engine-shaft, *S*, equal to 100 revolutions of the winding reel, *R*. The journal, on which the disk, *b*, is supported, projects beyond its face, and is provided at *h* with a pointer, *p*. The latter revolves with the disk. Between the disk and the pointer a dial, *d*, is interposed, which is fixed upon an independent support. As the disk is revolved the pointer moves on the face of the dial like a clock-finger, making, as before stated, one entire revolution for 100 turns of the reel on which the cable is wound. Its position, therefore, is always determined by the length of cable that is paid off from the reel. If the position of the pointer be once marked on the circumference of the dial, at points corresponding to any given depth in the mine-shaft, the engine driver can readily see the place of the cage at any moment of its ascent or descent.

The cages in the shaft are hoisted, lowered, or stopped by the engine driver, in answer to signals communicated to him from below. These are usually given by pulling a bell-wire, hung in the shaft, by means of which a gong or steel triangle, or other similar contrivance, is rung at the surface, the number of strokes indicating whether the cage is to be raised or lowered, or communicating some other necessary intelligence.

The usual method of conveying these signals is by ordinary iron wire, but it has many disadvantages, arising chiefly from the frequent breaking of the

wire, involving not only considerable expense of money and labor in replacing the same, but, what is more important, a great detention of the underground work, since, whenever such an accident occurs, all work of extraction must be suspended at such stations or levels where signal communication has been interrupted, and a number of men must consequently remain idle until repairs are completed. An improvement has lately been made, in some of the mines, by the substitution of half-inch ratlin rope, in place of the wire, which, for strength and durability, gives much greater satisfaction. The rope or wire is kept in place, near the side of the shaft, by iron staples, through which it moves freely.

To avoid the inconveniences just referred to, arising from the frequent breaking of the bell wire, a method of signalizing by electric telegraphy, not common in mines, was introduced by the Savage company in the spring of 1868. It gave great satisfaction for a time, but was afterward given up, owing to reasons not very definitely explained to the writer. It would appear, however, that its defects might be remedied, and the application of telegraphy to this purpose rendered useful.

The apparatus, as introduced at the Savage, consists of a battery, placed in the engine-room, with which two wires are connected, one leading to the ground, the other to a coil, fixed in a box near the engine driver, on the magnetic condition of which coil the striking of the gong depends. From this same coil another wire leads down the shaft to the station to be communicated with, where the end is received in a box, which also contains the end of another wire leading into the ground at the station. The earth is therefore used for completing the circuit. When the ends of the two wires, in the box at the station in the shaft, are disconnected, the circuit is broken; but, if they be brought together, it is complete, and the current, passing through the coil in the box in the engine-room, renders it magnetic, in which condition it acts upon an iron bar, so placed beneath it as to be lifted by attraction when the coil is magnetic, or to fall by its own weight when the coil is deprived of its magnetic force. By the movement of this bar the gong is struck and caused to ring. The battery employed in this arrangement is of the kind known as Hill's. It consists, in this instance, of thirty-two glass jars or cells, four inches in diameter and in depth, each cell furnished with a

zinc and a copper plate, and their connecting wires, in the usual way. They are placed in a little cabinet of shelves in the engine-room. The ground wire leads directly to the earth, in which the end is buried two or three feet deep. The other wire, having three branches, leads to three boxes, each containing a gong-apparatus, there being one for each hoisting compartment. The wire used for this purpose, and for connecting the gong-apparatus with the signal boxes at the stations in the shaft, consists of a small copper twist or rope of seven strands of wire, encased in a rubber coating. The metallic portion, twisted, is about one-tenth of an inch caliber. The whole, including the envelope, is about one-fifth of an inch thick.

The gong-apparatus consists of a light wooden box, containing the coil referred to, or, in fact, two coils, 5 or 6 inches long, and 2 or 3 in diameter. Two metallic, upright pieces, attached to the coils, pass upward through the top of the box. These uprights are each fitted with a perforated knob, one of which receives the wire leading from the battery, the other receiving the wire leading down the shaft. When, therefore, the circuit is completed by the connection of the shaft wire with the ground wire at the station, as before described, the current, passing through the coils, renders them magnetic, and attracts the iron bar by which the gong is rung. The contrivance for this purpose consists of a light iron bar, placed horizontally about half an inch below the coils, the end nearest the coil resting, when not lifted by magnetic attraction, on an adjustable support; the other end being pivoted, and permitting free angular motion of the bar whenever the magnetic coil exerts its attractive force upon it. The pivoted end forms a right angle like a bell-crank, so that, when one end of the bar is lifted by the coil, the other end, performing a corresponding movement, sets the gong hammer in motion. When the apparatus was first introduced the hammer was attached directly to this bar of iron; but, as it struck the gong with too little force, another arrangement was brought into use, consisting of a clock work, set in motion by a weight, and acting upon a strong spring carrying the gong-hammer, the clock work being restrained from action by a ratchet wheel, the teeth of which are in contact with the end of the iron bar just described. When the bar is lifted by magnetic action the ratchet wheel is released, the clock work set in motion, and the gong struck with force and clearness.

The apparatus at the signal stations in the shaft consists of a small box, in which two smaller but similar coils are placed, as in the gong boxes at the surface, just referred to. Two upright metallic pieces pass from the coils to the outside of the box, one of which, receiving the end of the shaft conducting wire, is in direct connection with the coils; the other upright, receiving the end of the ground wire, is not directly attached to the coils, but is so placed that a slight movement of a metallic spring is necessary to complete the connection. The spring, if drawn down, as it may be by hand, makes the circuit complete, and, when released, breaks it again immediately. The coils in this box are not essential, it only being necessary to connect the two wires, or the shaft conductor and the ground wire; they are only introduced to act as a magnet on another gong-apparatus, much smaller than, but similar to, that used at the surface, acting, however, without clock work, by which means a little gong is rung at the station, exactly as the gong rings above, when the signals are made, so that the operator, having his signals repeated, may know that it has been properly communicated to the engineer. The ground wire at the station is made long enough to reach the neighboring rock, where a hole is drilled a foot or two in depth, the wire inserted, and packed with moist earth.

There is a wire, with its connected boxes, for each compartment of the shaft; the signal gong for each compartment being placed directly in front of its appropriate engine. The three wires in the shaft, however, are all placed in the pump-compartment, being less liable to accident or derangement there. The cost of this entire apparatus is stated at about fifteen hundred dollars. It would appear to have some decided advantages for deep mines or extensive works. Its unsatisfactory performance in this instance is partly attributed to the uncertainty of the signals, some being caused by other means than the hand of the operator, owing, perhaps, to the ease with which the conducting wires may be accidentally brought into contact; a difficulty for which, it would seem, a simple remedy might be found. An objection to the use of this method is the impossibility of sending a signal to the engineer at the surface from points between stations. It is sometimes desirable to stop a cage at intermediate points either for work to be done there or on account of some accident. By the old arrangement the

bell-wire or rope can be reached from the cage and a signal communicated thereby.

When a cage arrives at the surface from the mine, bringing a loaded car, the latter is received by the attendant and disposed of according to its character. If the contents of the car be milling ore, it is moved upon a track to the ore-house and its load deposited in one of the bins; if the car contain waste-rock it is moved on through the ore-house to the waste-dump, and there discharged. The landing, or floor, about the mouth of the shaft, and at the intersection of tracks in the ore-house, is covered with boiler-plate, so that a car may easily be turned in any direction without the use of a turn-table. The ore-house has twelve bins of large capacity into which the ore, arriving at the surface from the mine, is dumped, to await transportation to the mills. The ore is delivered from the bins through sliding doors which are placed sufficiently high above the road to permit the wagon or car to stand underneath and receive its load without handling.

Each hoisting compartment of the mine shaft is provided, on its two open sides, with light gates that are made of stout iron wire, and so arranged as to slide up and down between guides. The ascending cage, reaching the mouth of the shaft, comes in contact with the gate and lifts it up, so that the way is open from the cage to the landing; as soon as the cage is lowered the gate resumes its place before the shaft-mouth. Before the introduction of this simple preventive some fatal accidents occurred, men having sometimes stepped into the shaft and fallen to the bottom. A case of this kind took place in the spring of 1868, when one of the attendants was pushing an empty car toward one of the compartments to await the arrival of the cage which was then below. Finding that the car was moving with too much speed he endeavored to check it, but without success, and in his attempts to prevent the car from falling into the shaft, held on to it so persistently that he lost control of himself and fell in with it.

The shops appertaining to these works are amply provided with all necessary facilities for the construction and repair of hoisting cages, cars, wheelbarrows, and similar machinery used in the mine; and there are timber-framing machines by means of which all the timbers used underground are easily and cheaply prepared. The value of this establishment is placed at $150,000 in the published statement of the assets of the company.


PUMPING AND HOISTING MACHINERY
OF THE
SAVAGE MINE.
Scale $\frac{1}{96}$
Section on Line A B C D of Plate XV

## SECTION II.

### COST AND YIELD OF ORES.

The general costs of mining on the Comstock lode are very large, owing chiefly to the high price of labor, and, further, to the great cost of such materials as timber, lumber, and fuel, of which the consumption is enormous. Labor is generally paid by the day or month, the contract system not being in great favor. Wages vary from $3 50 to $6 per day, in coin. Common laborers, wood passers, carmen, &c., obtain $3 50 to $4; miners, $4; head-miners, $6; carpenters, smiths, engine drivers, and other mechanics, $5 to $6, and in some cases more.

MATERIALS CONSUMED.—The cost and consumption of materials may be indicated by the following statements, taken from the reports of the Savage Mining Company, showing the quantity and value of the various materials used at their mine during two years past. Of the chief items, timber, lumber, and fuel, the former costs about $30 per thousand feet, board measure, and the latter little over $14 per cord. In these items a great reduction may be hoped for in future, as the railroad, now completed and in operation, connecting the mines with the Carson Valley, establishes cheaper transportation from the sources of supply.

*Quantity and Cost of Materials consumed at the Savage Mine during the year ending June 30, 1868.*

| Materials. | | Quantity. | Extracting ores. | Prospecting and dead work. | Accessory work. | Improvements. | Total cost value. |
|---|---|---|---|---|---|---|---|
| Timber - - - | feet | 2,075,567 | $37,943 91 | $9,455 04 | $13,288 02 | $1,984 29 | $62,671 26 |
| Lumber - - - | feet | 544,599 | 6,974 00 | 1,996 36 | 4,949 17 | 3,248 82 | 17,168 35 |
| Spiling - - - | pcs | 15,028 | 9 38 | 455 66 | 2,414 00 | 67 00 | 2,946 04 |
| Shingles - - | No. | 5,150 | - - - | - - - | - - - | 38 21 | 38 21 |
| Bricks - - - | No. | 33,700 | - - - | - - - | - - - | 606 60 | 606 60 |
| Lime - - - | lbs | 10,796 | - - - | - - - | - - - | 134 44 | 134 44 |
| Candles - - - | lbs | 38,500 | 4,817 63 | 2,373 33 | 2,576 30 | 72 05 | 9,838 31 |
| Wood - - - | cds | 3,456¼ | 19,491 43 | 13,729 20 | 15,655 70 | 64 50 | 48,940 53 |
| Charcoal - - | lbs | 10,228 | 1,184 41 | 621 94 | 728 74 | 937 07 | 3,472 16 |
| Stone coal - - | lbs | 16,925 | 24 77 | 14 00 | 240 75 | 624 13 | 903 65 |
| Powder - - - | kgs | 44½ | 100 00 | 73 75 | 48 75 | - - - | 222 50 |
| Iron - - - - | lbs | 78,086 | 440 90 | 151 78 | 4,629 10 | 2,080 96 | 7,302 74 |

*Quantity and Cost of Materials consumed at the Savage Mine, &c.*—Continued.

| Materials. | | Quantity. | Extracting ore. | Prospecting and dead work. | Accessory work. | Improvements. | Total cost value. |
|---|---|---|---|---|---|---|---|
| Steel - - - - | lbs | 4,854 | 533 40 | 62 65 | 144 24 | 429 36 | 1,169 65 |
| Nails - - - | lbs | 11,713 | 239 44 | 82 87 | 223 36 | 796 82 | 1,342 49 |
| Bolts, nuts, &c., | lbs | 5,482½ | 6 12 | 4 37 | 677 38 | 244 23 | 932 10 |
| Pick handles - | No. | 1,518 | 308 52 | 114 18 | 148 54 | 5 45 | 576 69 |
| Sledges - - - | No. | 27 | 79 37 | 28 03 | 12 37 | 10 20 | 129 97 |
| Sledge handles | No. | 264 | 47 04 | 8 34 | 32 06 | 33 | 87 77 |
| Saws - - - | No. | 32 | 38 61 | 27 08 | 48 80 | - - - | 114 49 |
| Wheelbarrows | No. | 1 | - - - | - - - | 12 50 | - - - | 12 50 |
| Brooms - - | No. | 56 | 13 77 | 10 83 | 20 03 | - - - | 44 13 |
| Car wheels - - | No. | 79 | 270 20 | 101 80 | 136 40 | - - - | 508 40 |
| Car axles - - | No. | 10 | 18 00 | 9 00 | 18 00 | - - - | 45 00 |
| Files - - - | No. | 406 | 112 17 | 47 03 | 97 07 | 9 61 | 265 88 |
| Fuse - - - - | feet | 4,598 | 142 67 | 87 90 | 74 50 | - - - | 305 07 |
| Rope - - - | lbs | 4,221⅓ | 334 98 | 187 56 | 349 68 | 176 98 | 1,049 20 |
| Canvas - - - | yds | 166¼ | - - - | 26 21 | 49 35 | - - - | 75 56 |
| Lard oil - - | gals | 850 | 713 47 | 231 27 | 508 00 | 7 60 | 1,460 34 |
| Kerosene - - | gals | 849½ | 270 40 | 113 70 | 287 00 | 8 40 | 679 50 |
| Paraffine - - | gals | 55 | 35 25 | - - - | 26 65 | - - - | 61 90 |
| Tallow - - - | lbs | 7,598 | 296 94 | 216 59 | 398 47 | - - - | 912 00 |
| Lamp chimneys | No. | 185 | 11 19 | 8 75 | 12 40 | - - - | 32 34 |
| Lamp wick - | No. | 74 | - - - | - - - | 3 04 | - - - | 3 04 |
| Water buckets | No. | 88 | 26 89 | 7 15 | 19 19 | 1 72 | 54 95 |
| Gas pipe - - | feet | 997 | - - - | 220 32 | 329 53 | - - - | 549 85 |
| Leather - - - | lbs | 215 | - - - | - - - | 64 60 | 19 52 | 84 12 |
| Shovels - - - | No. | 435 | 227 59 | 98 75 | 176 25 | 41 25 | 543 75 |
| Axes - - - - | No. | 62 | 47 74 | 23 89 | 45 50 | - - - | 117 13 |
| Axe handles - | No. | 27 | 5 20 | - - - | 1 20 | 4 40 | 10 80 |
| Gum packing - | lbs | 698½ | 9 00 | 3 00 | 35 25 | 639 29 | 686 54 |
| White lead - - | lbs | 187 | - - - | - - - | - - - | 38 00 | 38 00 |
| Borax - - - - | lbs | 192 | 23 16 | 4 75 | 20 52 | - - - | 48 43 |
| Hay - - - - | lbs | 34,202 | - - - | - - - | 949 38 | - - - | 949 38 |
| Barley - - - | lbs | 5,886 | - - - | - - - | 289 90 | - - - | 289 90 |
| Bran - - - - | lbs | 4,813 | - - - | - - - | 244 31 | - - - | 244 31 |
| Oats - - - - | lbs | 11,255 | - - - | - - - | 565 53 | - - - | 565 53 |
| Water - - - - - | | - - - | 2,465 00 | - - - | 2,465 00 | - - - | 4,930 00 |
| Whiting - - - | lbs | 196 | 8 25 | 3 50 | 4 65 | - - - | 16 40 |
| Sundries - - - - | | - - - | 1,863 18 | 982 39 | 13,508 93 | 15,893 17 | 32,247 67 |
| | | | 79,133 89 | 31,581 47 | 66,530 11 | 28,184 40 | 205,429 87 |

Under the head of "Sundries" are comprised iron pipe, galvanized pipe, screws, asphaltum, steel wire rope, copper wire, steam drum, spirit level, tar, turpentine, paints and oils, varnish, belting, pump-columns, foundery work, stone work, cement, electric signal apparatus, appurtenances to machinery, &c.

*Quantity and Cost of Materials consumed at the Savage Mine during the year ending June 30, 1869.*

| Materials. | | Quantity. | Extracting ore. | Prospecting and dead work. | Accessory work. | Improvements. | Total cost value. |
|---|---|---|---|---|---|---|---|
| Timber - - - | feet | 1,352,716 | $18,203 45 | $5,866 11 | $13,312 18 | $807 40 | $38,189 14 |
| Lumber - - - | feet | 363,388 | 4,147 50 | 2,230 29 | 3,531 66 | 992 19 | 10,901 64 |
| Spiling - - - | pcs | 10,057 | 34 60 | 395 20 | 1,581 60 | - - - | 2,011 40 |
| Shingles - - | No. | 2,250 | - - - | - - - | - - - | 18 50 | 18 50 |
| Candles - - | lbs | 33,440 | 2,924 07 | 1,466 49 | 1,881 82 | 7 60 | 6,279 98 |
| Wood - - - | cds | 3,333 | 21,247 50 | 11,394 00 | 14,154 50 | 28 00 | 46,824 00 |
| Charcoal - - | bush | 8,758 | 1,012 20 | 613 20 | 958 65 | 481 25 | 3,065 30 |
| Stone coal - - | lbs | 13,628 | 32 91 | 35 95 | 382 36 | 82 91 | 534 13 |
| Powder - - - | kgs | 108 | 259 06 | 179 80 | 62 60 | - - - | 501 46 |
| Powder, (Giant,) | lbs | 78 | | | | | |
| Iron - - - - | lbs | 19,490 | 239 10 | 83 43 | 1,051 56 | 228 88 | 1,602 97 |
| Steel - - - - | lbs | 3,903 | 451 29 | 79 55 | 323 56 | 14 15 | 868 55 |
| Nails - - - | lbs | 7,288 | 229 11 | 87 99 | 246 24 | 185 72 | 749 06 |
| Bolts, nuts, &c., | lbs | 808 | 2 75 | 10 60 | 113 50 | 36 27 | 163 12 |
| Pick handles - | No. | 1,587 | 304 97 | 113 11 | 185 07 | 5 27 | 608 42 |
| Sledges - - - | No. | 39 | 62 25 | 25 75 | 59 00 | - - - | 147 00 |
| Sledge handles | No. | 255 | 50 30 | 14 65 | 35 70 | - - - | 100 65 |
| Shovels - - - | No. | 312 | 199 21 | 92 34 | 145 10 | 1 75 | 438 40 |
| Axes - - - | No. | 79 | 35 50 | 18 73 | 69 13 | 5 43 | 128 79 |
| Saws - - - | No. | 29 | 37 20 | 4 94 | 48 92 | - - - | 91 06 |
| Wheelbarrows[1] | No. | 24 | | | | | |
| Brooms - - - | No. | 67 | 15 50 | 2 75 | 27 10 | - - - | 45 35 |
| Cars[1] - - - | No. | 12 | | | | | |
| Files - - - | No. | 387 | 96 58 | 29 62 | 102 75 | 7 43 | 236 38 |
| Fuse - - - - | feet | 9,550 | 58 00 | 25 00 | 15 50 | - - - | 98 50 |
| Rope, (Manilla,) | lbs | 2,285 | 197 50 | 51 81 | 261 93 | 9 20 | 520 44 |
| Canvas - - - | yds | 309 | 25 00 | 25 10 | 117 71 | 6 00 | 173 81 |
| Castor oil - - | gals | 155 | 110 38 | 61 87 | 134 64 | - - - | 306 89 |
| Lard oil - - | gals | 357 | 270 24 | 68 28 | 235 38 | - - - | 573 90 |
| Paraffine oil - | gals | 90 | 53 84 | 7 25 | 42 95 | - - - | 104 04 |
| Kerosene - - | gals | 666 | 176 97 | 53 74 | 179 64 | 1 50 | 409 85 |
| Tallow - - - | lbs | 5,547 | 254 11 | 182 10 | 256 87 | 25 | 693 44 |
| Lamp chimneys | No. | 115 | 9 94 | 6 51 | 7 52 | - - - | 23 97 |
| Lamp wicks - - - | | - - - | 2 00 | 04 | 4 83 | - - - | 6 87 |
| Water buckets | No. | 42 | 18 60 | 3 10 | 10 86 | - - - | 32 56 |
| Gas pipe - - | feet | 271 | - - - | - - - | 111 63 | 12 25 | 123 88 |
| Leather - - - | lbs | 460 | - - - | 41 78 | 100 47 | - - - | 142 25 |
| White lead - - | lbs | 141 | - - - | - - - | 11 10 | 14 40 | 25 50 |

*Quantity and Cost of Materials consumed at the Savage Mine, &c.*—Continued.

| Materials. | | Quantity. | Extracting ore. | Prospecting and dead work. | Accessory work. | Improvements. | Total cost value. |
|---|---|---|---|---|---|---|---|
| Borax | lbs | 123 | 20 35 | 7 12 | 16 00 | - - - | 43 47 |
| Hay | lbs | 20,103 | - - - | - - - | 450 31 | - - - | 450 31 |
| Barley | lbs | 705 | - - - | - - - | 40 54 | - - - | 40 54 |
| Bran | lbs | 4,698 | - - - | - - - | 193 97 | - - - | 193 97 |
| Oats | lbs | 8,153 | - - - | - - - | 405 86 | - - - | 405 86 |
| Water | | - - - | 2,510 00 | - - - | 2,510 00 | - - - | 5,020 00 |
| Sundries | | - - - | 114 63 | 118 11 | 8,430 86 | 6,479 65 | 15,143 25 |
| | | | 53,406 61 | 23,394 31 | 51,811 57 | 9,426 00 | 138,038 49 |

[1] Wheelbarrows and cars manufactured at the mine and cost included in the items of lumber, iron, and labor.

Cost value of materials on hand, July 1, 1868 . . . . . . . . . . . . . $21,340 01

Cost value of materials on hand, July 1, 1869 . . . . . . . . . . . . . 23,527 67

Under the head of "Sundries" are comprised foundery work, repairs to boilers, pump fixtures, steam feed-pump, valves, Babbit-metal, screws, gas pipe fixtures, packing, cotton waste, sulphate of copper and of zinc, wire, hose and hose-pipes, gum coats and gum boots, tar, belting, paints and oils, jack screws, circular saws, hardware, &c.

Costs of Mining.—The cost, per ton, of mining ore in the mines of the Comstock lode may be seen by the following statements, prepared from the reports of some of the leading companies, whose accounts furnish the desired data in the most available form.

The first statement presents, in one table, the mining costs of several mines during three or four years. These figures include nothing for milling or metallurgical treatment; they apply simply to actual mining costs or expenses incidental to carrying on the business. In this respect it must be observed that the apparently large differences between the figures of the several companies, as, for instance, the Savage and the Imperial, are chiefly due to the difference in methods of presenting the accounts, some of them including in their statement of costs nothing more than the actual expense of mining and extracting the ore in question, or of such dead work as actually applies to that part of the business, while others comprise the additional items of prospecting, opening new ground, repairs, improvements, office labor, and all the

incidental expenses of carrying on the entire operations of the mine. It is obvious that if the expense of all this work, generally very large, be applied to the quantity of ore raised from the productive portion of the mine, the costs, per ton, will appear much larger than they would if only the actual expense of extraction were considered. Thus in the tabular statement here presented the lowest cost of mining, per ton, in the Savage mine, is given at $7 21; while in the Imperial the cost in one year is as low as $3 54, for the Holmes mine, and is generally less than $5. In the case of the Savage every item of expense that may reasonably be charged to the business of mining is included in the account, whereas in the Imperial the given figures apply only to work performed in reaching and extracting the quantity of ore on which the calculation is based, including nothing of the cost of sinking the new shaft, unproductive work or other incidental expenses. If the accounts of the several mines were prepared on exactly the same basis, the differences in the figures would be but little.

Another cause of difference in the cost of mining in the several mines, or between various years of the same mine, is to be found in the varying relation existing between the amount of unproductive work performed and the quantity of ore extracted. Thus in the Savage mine the costs of extraction, per ton, in the year ending June 30, 1866, are stated at $18 06; while in the two succeeding years the average is about $7 55, the difference being mainly due to the fact that in 1866 the outlay for dead work, improvements, and equipment was large, while the quantity of ore extracted in that year was but little over one-third of the quantity produced in either of the two years following; the proportionate expense of this work, per ton, of course, increasing as the quantity decreases.

It is difficult therefore to give a correct idea of mining costs except by minutely analyzed accounts, and these are given for some of the companies, with more or less detail, in the statements which follow.

*Statement showing Mining Costs, per ton of ore extracted, in several mines of the Comstock lode.*

| Mine. | During fiscal year ending in— | | | |
|---|---|---|---|---|
| | 1866. | 1867. | 1868. | 1869. |
| | Per ton. | Per ton. | Per ton. | Per ton. |
| Gould and Curry | $7 86 | $11 35 | - - | $7 29 |
| Savage | 18 06 | 7 91 | $7 21 | 8 90 |
| Hale and Norcross | - - | 9 08 | | |
| Chollar-Potosi | 5 99 | 4 48 | 4 24 | 4 30 |
| Chollar-Potosi, including prospecting | - - | 6 39 | 6 93 | 7 94 |
| Imperial, (Holmes mine) | 3 63 | 3 54 | 4 74 | |
| Imperial, (Alta mine) | 5 27 | 4 36 | 4 96 | 4 73 |
| Imperial, additional cost in sinking new shaft | 1 34 | 1 56 | 2 36 | |
| Crown Point | 8 97 | 7 50 | 9 85 | 9 80 |
| Kentuck | - - | 9 22 | 9 81 | 8 67 |

The following statement shows the detailed costs of mining, per ton of ore extracted, in the Gould and Curry mine during two years.

| | Year ending Nov. 30, 1866. | | Year ending Nov. 30, 1867. | |
|---|---|---|---|---|
| Tons of ore produced | 62,425 | - - | 24,940 | |
| | Amount. | Per ton. | Amount. | Per ton. |
| Cost of officials | $13,254 00 | $0 21 | $4,010 00 | $0 16 |
| Extracting ore | 193,822 72 | 3 10 | 106,625 25 | 4 27½ |
| Prospecting and dead work | 131,697 09 | 2 11 | 121,097 60 | 4 85¾ |
| Accessory work | 113,846 46 | 1 82 | 35,865 87 | 1 43¾ |
| Improvements | 38,502 25 | 0 62 | 15,431 81 | 62 |
| Total cost of mining | 491,122 52 | 7 86 | 283,031 53 | 11 35 |
| Additional general expenses in Virginia City and San Francisco. | - - - - | 92 | - - - - | 2 13 |
| | | 8 78 | | 13 48 |

The following is a similar statement, prepared from the reports of the Savage Mining Company, showing the detailed costs, per ton, of production; to which are added the cost of reduction of the ore, the average yield, and the profit of each ton during three years.

| | Year ending July 1, 1867. | | Year ending July 1, 1868. | | Year ending July 1, 1869. | | | |
|---|---|---|---|---|---|---|---|---|
| Tons of ore produced - - - | 70,721 | | 87,342 | | 53,954 | | | |
| | Amount. | Per ton. | Amount. | Per ton. | | Amount. | Per ton. | Per ton. |
| Cost of officials - - - - - - | $23,700 33 | $0 33 | $24,575 00 | $0 28 | - - - - | $22,123 83 | - - - | $0 41 |
| Extracting ore - - - - - - | 195,380 18 | 2 77 | 235,817 03 | 2 70 | Labor - | 153,675 75 | $2 85 | - - - |
| | | | | | Materials | 53,406 61 | 99 | 3 84 |
| Prospecting and dead work - | 69,154 39 | 98 | 69,475 88 | 79 | Labor - | 34,838 00 | 65 | - - - |
| | | | | | Materials | 23,394 31 | 43 | 1 08 |
| Accessory work - - - - - | 88,836 15 | 1 25 | 149,607 57 | 1 71 | Labor - | 79,398 62 | 1 47 | - - - |
| | | | | | Materials | 50,914 86 | 95 | 2 42 |
| Improvements - - - - - - | 94,120 27 | 1 33 | 49,361 59 | 57 | Labor - | 7,105 50 | 13 | - - - |
| | | | | | Materials | 9,426 00 | 17 | 30 |
| Total costs of mining - - - | 471,191 32 | 6 66 | 528,837 07 | 6 05 | Labor - | 297,141 70 | 5 51 | - - - |
| | | | | | Materials | 137,141 78 | 2 54 | 8 05 |
| INCIDENTAL. | | | | | | | | |
| Assaying ore - - - - - - | 5,096 50 | 07 | 7,548 25 | 09 | - - - - | 3,528 19 | - - - | 07 |
| Assaying bullion - - - - - | 15,244 52 | 22 | 23,551 93 | 26 | - - - - | 8,740 82 | - - - | 17 |
| Surveying - - - - - - - - | 1,807 75 | 02 | 2,330 00 | 03 | - - - - | 1,850 00 | - - - | 03 |
| Office expenses - - - - - | 3,369 64 | 05 | 1,837 77 | 02 | - - - - | 1,157 60 | - - - | 02 |
| Exchange - - - - - - - | 7,128 15 | 11 | 7,532 58 | 09 | - - - - | 3,254 70 | - - - | 06 |
| Horse-keeping - - - - - - | 2,062 65 | 03 | 2,354 50 | 03 | - - - - | 2,843 15 | - - - | 05 |
| Legal expenses - - - - - | 21,856 98 | 31 | 7,817 00 | 09 | - - - - | 2,200 00 | - - - | 04 |
| Taxes - - - - - - - - - - | 20,937 52 | 29 | 40,342 61 | 46 | - - - - | 19,486 73 | - - - | 36 |
| Sundries - - - - - - - - | 10,886 49 | 15 | 7,768 78 | 09 | - - - - | 3,017 19 | - - - | 05 |
| Cost of production - - - - | 559,581 52 | 7 91 | 629,920 49 | 7 21 | - - - - | 480,361 86 | - - - | 8 90 |
| Cost of reduction - - - - | 974,433 23 | 14 04 | 1,162,957 08 | 13 74 | - - - - | 678,088 52 | - - - | 12 22 |
| | 1,534,014 75 | 21 95 | 1,792,877 57 | 20 95 | - - - - | 1,158,450 38 | - - - | 21 12 |
| Average yield of all ore reduced - - - - | | 41 94 | - - - - - | 40 84 | - - - - | - - - - - - | - - - | 34 87 |
| Average profit per ton - - | - - - - - | 19 99 | - - - - - | 19 89 | - - - - | - - - - - - | - - - | 13 75 |

The Hale and Norcross Mining Company's report for the year ending March, 1867, furnishes the following statement of costs of mining 29,401 tons of ore:

| | Per ton. |
|---|---|
| Managerial cost | $0 31.7 |
| Hoisting power | 2 38.7 |
| Mining cost | 4 79.0 |
| Improvement cost | 65.9 |
| Relative expense, (weighing, sampling, and contingent) | 92.9 |
| | 9 08.2 |

The following are analytical statements of the disbursements of the same company during two years, showing the sums expended for the several items, the percentage of each, and the amount per ton:

| | Year ending March, 1867. | | | Year ending March, 1868. | | |
|---|---|---|---|---|---|---|
| Number tons produced | 29,401 | - - | - - | 25,432 | | |
| | Sums. | Per ton. | Per cent. | Sums. | Per ton. | Per cent. |
| For accounts of previous year | $6,092 68 | $0 21 | .44 | | | |
| Salaries | 9,980 76 | 0 34 | .73 | $9,000 00 | $0 35 | .78 |
| Mine account, including labor and materials employed in the mine. | 190,187 36 | 6 47 | 13.86 | 208,304 92 | 8 19 | 18.14 |
| Firewood | 30,784 91 | 1 05 | 2.24 | Included in mine account. | | |
| Working ores | 408,366 44 | 13 89 | 29.74 | 360,105 63 | 14 16 | 31.35 |
| Real estate | 5,727 04 | 20 | .42 | 584 21 | 02 | .05 |
| Taxes | 11,113 90 | 38 | .81 | 12,404 04 | 49 | 1.08 |
| Freight | 10,575 64 | 36 | .77 | 11 349 02 | 44 | .99 |
| Sinking Fair shaft | 11,560 65 | 40 | .84 | 212 684 85 | 8 36 | 18.52 |
| In advance to superintendent | 6,442 93 | 22 | .47 | 3,734 25 | 15 | .32 |
| Law expenses and fees | 33,997 30 | 1 15 | 2.47 | 10,015 83 | 40 | .87 |
| Machinery | 6,266 42 | 22 | .46 | | | |
| Assays | 10,424 17 | 35 | .76 | 7,912 06 | 31 | .70 |
| Miscellaneous expenses | 8,168 80 | 27 | .60 | 12,245 87 | 48 | 1.07 |
| Dividends | 490,000 00 | 16 66 | 35.69 | 300,000 00 | 11 80 | 26.12 |
| Cash on hand | 133,288 99 | 4 53 | 9.70 | 183 93 | 01 | .01 |
| | 1,372,977 99 | 46 70 | 100. | 1,148,524 61 | 45 16 | 100. |

The cost of mining labor, per ton of ore extracted, is stated in later reports at \$9 01$\frac{6}{10}$, for year ending February, 1869; and at \$5 13$\frac{8}{10}$ for year ending February, 1870.

The following are analyzed statements of mining costs in the Chollar-Potosi mine:

*Statement of Mining Costs, including nothing for Milling,*[1] *of the Chollar-Potosi mine during the year ending May* 31, 1868.

| Tons of ore produced by company, 70,340. *a* | Extracting ore. | | Sinking new shaft, repairs, and pumping. | | Prospecting. | |
|---|---|---|---|---|---|---|
| | Sums. | Per ton. | Sums. | Per ton. | Sums. | Per ton. |
| Wages | $205,255 22 | $2 92 | $38,238 00 | | $27,024 25 | |
| Miscellaneous supplies | 21,079 91 | 30 | 10,377 70 | | 5,583 94 | |
| Timber and lumber | 58,189 70 | 83 | 11,080 25 | | 3,984 82 | |
| Firewood | 9,248 00 | 13 | 3,555 00 | | 2,962 50 | |
| Coal | 1,513 25 | 02 | 1,736 00 | | 597 75 | |
| Water | 1,882 50 | 02½ | 1,200 00 | | 620 00 | |
| Ore assays | 1,153 50 | 01½ | | | | |
| | 298,322 08 | *b* 4 24 | 66,187 33 | $0 94 | 40,773 26 | $0 58 |

| Statement, &c., continued. | Sums. | Per ton. |
|---|---|---|
| Extracting ore, as per foregoing | $298,322 08 | $4 24 |
| New shaft, as per foregoing | 66,187 33 | 94 |
| Prospecting, as per foregoing | 40,773 26 | 58 |
| Filling mine, at old works | 10,843 50 | 15.4 |
| Dead work at old works | 12,632 50 | 18 |
| Machinery and repairs | 22,855 50 | 32.5 |
| Freight | 3,957 35 | 05.6 |
| Legal | 1,998 60 | 02.8 |
| Surveying | 1,200 00 | 01.7 |
| Stable | 1,455 89 | 02 |
| Taxes | 15,884 36 | 22.6 |
| Exchange | 3,571 73 | 05 |
| Office and house repairs | 2,033 03 | 03 |
| Sundries | 6,069 80 | 08.5 |
| | 487,784 93 | 6 93 |

[1] Milling costs, per ton . . . $14 75
Add mining costs . . . 6 93

Total cost . . . 21 68

Average yield . . . 24 14
Average profit . . . 2 46

*a* All run out through tunnel without hoisting.
*b* $17.58 per cent. of yield of the ore.

*Statement of Mining Costs, including nothing for Milling,*[1] *of the Chollar-Potosi mine during the year ending May* 31, 1869.

| Tons of ore produced, 44,900. | Extracting ore. | | New shaft and prospecting work. | |
|---|---|---|---|---|
| | Sums. | Per ton. | Sums. | Per ton. |
| Wages | $147,859 19 | $3 29 | $68,261 25 | |
| Miscellaneous supplies | 5,349 02 | 12 | 9,011 33 | |
| Timber | 34,418 39 | 76½ | 9,557 38 | |
| Iron and steel | 1,035 68 | 2½ | 2,391 52 | |
| Coal | 1,080 00 | 2½ | 2,227 83 | |
| Candles | 3,416 92 | 7½ | 1,320 55 | |
| Oils and tallow | . . . . . . | . . . | 1,839 34 | |
| Wood | . . . . . . | . . . | 22,675 75 | |
| Water | . . . . . . | . . . | 2,590 00 | |
| | 193,159 20 | *b*4 30 | 119,874 95 | $2 67 |

| Statement, &c., continued. | Sums. | Per ton. |
|---|---|---|
| Extracting ore, as per foregoing | $193,159 20 | $4 30 |
| New shaft, as per foregoing | 119,874 92 | 2 67 |
| Dead work in old mine | 2,668 50 | 06 |
| Machinery and repairs | 10,122 04 | 22.5 |
| Freight | 6,962 18 | 15.5 |
| Legal | 3,976 25 | 09 |
| Surveying | 360 00 | 00.7 |
| Stable | 2,358 34 | 05 |
| Taxes | 5,902 65 | 13 |
| Exchange | 1,731 88 | 04 |
| Office and house expenses | 1,253 64 | 03 |
| Assaying | 3,768 22 | 08 |
| Sundries | 4,783 93 | 10.5 |
| | 356,921 75 | 7 94 |

[1] Milling costs, per ton — $13 15
Add mining costs — 7 94

Total cost — 21 09

Average yield of ore — 23 70
Average profit — 2 61

*b* 18.15 per cent. of yield of ore.

In the accounts just given of the Chollar-Potosi it should be observed that all ore extracted came from the old works, (excepting 119 tons in 1868,) and little, if any, was hoisted from any considerable depth, but run out to the surface by way of tunnel. The costs of sinking the new shaft, in the eastern country-rock, and of prospecting the ground in connection with it, are stated in such manner as to show the expense, per ton of ore produced, for carrying on that work; but of all the ore in question only 119 tons came from the shaft or connected works, the whole, with the exception above made, having been produced, as first stated, in the old mine.

The work performed at the new shaft for the outlay shown in the foregoing accounts was, during year ending May 31, 1868, as follows:

| | Feet. |
|---|---|
| Sinking vertical shaft, from a depth of 651½ feet to a depth of 930 feet, in all | 278½ |
| Sinking the incline shaft from bottom of last named, (including cost of timbering, repairs, placing pumps, and operating hoisting works) | 241 |
| Sinking winze | 106 |
| Drifting | 1,278 |

| | |
|---|---|
| Costing, as shown in statement, | $106,960 59 |
| In addition to which there was expended for machinery and freight | 25,105 27 |

The work performed in this department, during the year ending May 31, 1869, was as follows:

| | | Feet |
|---|---|---|
| Sinking the incline, below point already reached, 1,169 feet from surface to point, 1,392 feet from surface | | 223 |
| Drifting on 500-foot station | 514 feet. | |
| Drifting on 920-foot station | 280 feet. | |
| Drifting on 1,000-foot station | 145 feet. | |
| Drifting on 1,100-foot station | 994 feet. | |
| Drifting on 1,240-foot station | 330 feet. | |
| Total | 2, 263 feet. | |

The outlay for this work, as shown in the foregoing statements, includes all cost for timbering, repairing, placing pumps, and operating the hoisting, and pumping machinery.

Concerning the stated costs of mining in the Imperial and the Crown Point mines, as given in the first table referring to this subject, there are no detailed analyses presented in the published reports of those companies. It may be repeated, however, that, in the case of the Imperial, the figures given for the Holmes and Alta mines apply only to the mining of the ore, or to what, in the accounts of the Savage and Chollar-Potosi, is termed "extraction;" they include all costs of drifting, timbering, repairs, and general labor, in that portion of the mine from which the ore in question was produced, but do not include the cost of sinking the new prospecting shaft, or of carrying on work not directly connected with the production of ore.

The amount expended by the Imperial in prospecting or dead work, divided by the number of tons of ore raised from the productive portion of the mine, shows the cost per ton applied to this purpose, which is stated as an additional item in the table referred to; but neither of the items given includes general and incidental expenses, such as assaying, taxes, legal and office expenses, freight, &c., which form a part of the statements of the Savage, Chollar, and other companies.

From the foregoing statements it appears that the cost of merely mining or extracting the ore may vary between \$3 and \$5 per ton; that the incidental expenses, necessary for the administration and maintenance of the business, increase the cost, under ordinary circumstances, to \$7, \$8, or \$10; and beyond that amount indefinitely, according to the relation existing between the quantity of ore produced and the outlay for improvements, repairs, or other extraordinary expenses.

The expense of moving the ore from the mine to the mill, and the cost of, or price paid for, milling, which will be discussed in detail in the following chapter, vary in general between \$10 and \$14 per ton; so that the total cost of production and reduction of the ore amount to \$20 per ton and upward. Thus, the expense in the Savage, during three years past, has been, on the average, \$21 28 per ton; in the Chollar-Potosi, during two years, \$21 37; and, if the accounts for each year of other large producing companies be care-

fully examined, and the total amount of their expenses divided by the number of tons of ore produced, the result will rarely fall below and generally exceed the figures just given.

Yield of Ores.—In connection with this subject the following tabular statement is herewith presented, showing the number of tons of ore produced annually by several of the principal mines during four or five years past, and the average yield per ton of their product. By comparing the figures of this table with those just given, the relation of cost of production to the yield of ore may be easily seen.

Concerning this table, it may be observed that the figures showing the product include the whole quantity of ore raised from any given mine during either of the years for which it is stated; while the figures showing the yield per ton apply simply to the quantity of ore reduced, during the given year, by the company or mine in question. It is only in rare instances that the number of tons reduced, or treated for the extraction of their precious metals, is exactly the same as that produced from the mine, and, in some cases, the difference is large. Thus, in the figures referring to the Savage and to the Chollar-Potosi, during the last two years, there are, in the aggregate, many thousand tons included in the stated product, to which the figures showing the yield per ton do not apply, because the product comprises the quantity of ore produced from the mine by the company and contractors together, while the yield is only that of the ore treated by the company exclusively. The table may not, therefore, be depended upon to show exactly the operations of the companies or mines named in it, its purpose being only to give a general idea of the rate of production from the leading claims, and the average yield per ton of ore.

The figures showing the yield express the value actually obtained, by milling process, from the ore in question, averaging all classes. The relation of this yield to the assay value, or that actually contained in the ore, as well as the relative proportions of gold and silver, will be shown more clearly in the following chapter.

It is also to be observed that the great bulk of ore raised is of the quality generally denominated as third-class, yielding from \$20 to \$40 per ton; the quantity of higher grades being generally insignificant, especially during recent years.

*Statement showing product and yield of ores of leading mines on the Comstock lode.*

| Mine. | During fiscal year ending in 1865. | | During fiscal year ending in 1866. | | During fiscal year ending in 1867. | | During fiscal year ending in 1868. | | During fiscal year ending in 1869. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons of ore produced from the mine. | Average yield of ores reduced.[1] | Tons of ore produced from the mine. | Average yield of ores reduced. | Tons of ore produced from the mine. | Average yield of ores reduced. | Tons of ore produced from the mine. | Average yield of ores reduced. | Tons of ore produced from the mine. | Average yield of ores reduced. |
| Gould and Curry - - - - | 47,217 | $45 41 | 62,425 | $28 47 | *c* 24,940 | $24 26 | 12,153 | $18 14 | 15,879 | $26 30 |
| | *b* 470½ | 255 66 | *b* 8 | - - | *a* 5 | 511 25 | | | | |
| | *a* 1½ | | | | | | | | | |
| Savage - - - - - - - - - | - - | - - | 30,653 | 42 38 | 70,721 | 41 94 | [2]87,342 | 40 84 | [2]69,287 | 34 87 |
| | | | *a* 435½ | 224 08 | *a* 88½ | - - | *a* 277½ | 359 52 | *a* 68¼ | 220 32 |
| | | | *b* 26,338 | 42 04 | *b* 15,666½ | - - | *b* 4,745 | 78 16 | | |
| | | | *c* 3,878 | 20 43 | *c* 54,966 | - - | *c* 78,422 | 37 31 | | |
| Hale and Norcross - - - - | - - | - - | - - | - - | 29,401 | 47 32 | 25,432 | 34 14 | 16,803 | 23 89 |
| Chollar-Potosi - - - - - | - - | - - | - - | - - | 57,799 | 25 73 | [2]95,985 | 24 14 | [2]97,841 | 23 70 |
| | | | | | | | *a* 9 | | | |
| Imperial, (Alta mine) - - - | 28,067 | 30 26 | 32,255 | 30 51 | 29,616 | 28 00 | 31,491 | 22 09 | 42,958 | 13 37 |
| Imperial, (Holmes mine) - - | 170 | 31 05 | 2,927 | 12 89 | 11,262 | 20 49 | 8,764 | 20 11 | 2,214 | 11 64 |
| Empire - - - - - - - - - | 22,870 | 30 28 | 22,923 | 21 86 | 15,027 | 21 92 | 11,028 | 20 00 | | |
| Yellow Jacket - - - - - | 49,013 | 33 06 | 55,009 | 32 51 | 84,340 | 31 73 | 34,718 | 19 50 | | |
| Kentuck - - - - - - - - | - - | - - | - - | - - | [3]15,834 | 43 86 | 31,390 | 40 06 | 26,866 | 29 99 |
| Crown Point - - - - - - | 3,766 | 35 60 | 18,259 | 37 73 | 34,750 | 35 91 | 25,964 | 33 34 | 25,833 | 32 73 |

[1] The average yield is about 70 per cent. of the actual value contained.
[2] Including that extracted by contractors.
[3] Six months.

*a* First class. *b* Second class. *c* Third class.

CONDITIONS OF THE FUTURE AFFECTING COSTS.—The Comstock lode, judged by present appearances, would hold out but doubtful promise for the future, if there were no hope of greatly reducing the present costs of mining and milling.

There has been, during the last few years, a steady decrease in the value of the ores raised from the mines, as the foregoing table makes plainly evident; while some of the mines that, until lately, have contributed most largely to the annual bullion production of the lode, are rapidly exhausting the deposits hitherto supplying ore, or have already done so. The deeper explorations of those mines which furnished large products from ground within 500 or 600 feet of the surface, such as the Ophir, Gould and Curry, Chollar-Potosi, Empire and Imperial, have thus far afforded little or no encouragement; so that, while fortunate discoveries of new ore-bodies in the

bottom of the mines may, at any day, reward the persistent efforts of those companies that are still searching for them, and so restore confidence in the deeper portion of the lode, there is, to say the least, no positive assurance of such results at present.

Whatever good or ill fortune may attend the explorations of the lode in depth, there is still much hope for a long-continued bullion production and remunerative mining industry, in the existence of large bodies of ore near the surface, that, until now, have remained undeveloped by reason of their low value, being too poor to pay for mining and milling, at prices hitherto existing, but offering a margin of profit, under conditions that seem possible for the future.

It is believed that there are very extensive deposits of low-grade ore in various parts of the lode. In the Chollar-Potosi alone there are large bodies of quartz, lying near the surface and easily available for cheap mining, which, it is believed, can be worked profitably when the costs of both mining and milling are reduced, as they seem likely to be, by the operation of the Virginia and Truckee railroad. This road bids fair to lessen considerably the cost of materials used in the mines, and to afford cheap transportation for the ore to mills that are driven by water power, thus diminishing the expense of three important items—materials, transportation, and power. If this be aided by a reduction in cost of labor, which seems unavoidable, for the high wages at present are quite out of proportion to costs of living, the business of the district should still possess some elements of continued prosperity, quite independent of the results of deep explorations.

Virginia and Truckee Railroad.—This road was built during 1868 and 1869, and completed and opened for operation late in the last-named year. Its name and charter implies the design to connect the cities of Virginia and Gold Hill, where the mines of the Comstock are situated, with the Central Pacific railroad, at the Truckee River. This will probably be accomplished in time to come, but the road, at present, extends from the mining region only to Carson, with a branch from that point toward the mountains, three or four miles in length, and reaching thus the source of supply of timber, lumber, and fuel. The road is 28 miles long, and corresponds with the Central Pacific railroad in gauge, weight of iron, and method of constructon. Its cost is stated

at $1,500,000. From Virginia and Gold Hill the road descends to the level of the Carson River Valley, passing through country that involved some heavy expenses in construction of the line, but in which the highest grade adopted but little exceeds 100 feet per mile. Striking the river at the nearest available point it follows along its course within easy reach of the mills that are situated along the river, and deriving their power from it. From Carson the branch track is laid directly up to the foot-hills of the mountains, so as to receive timber and fuel at the mouth of the cañon or valley from which these supplies are obtained. Higher up in the mountains, and along the sides of the cañons, there still remain extensive tracts of woodland, affording large supplies of timber and fuel. Saw-mills are conveniently established there, and engaged in manufacturing lumber, many varieties of which, together with all the cordwood, are delivered cheaply at the mouth of the cañon, the present terminus of the railroad track, by means of a flume.[1] The cost of cutting cordwood is, at present prices, $2 50 per cord, and of moving it from the

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[1] This flume consists of a V-shaped launder or trough, made of two-inch plank, 18 or 20 inches wide, supported by a light trestle-work, and in which a rapidly flowing stream of water carries down cordwood or timber (of such length as the curves of the flume will permit the passage of) from the head of the cañon to its mouth. In a flume of this description, now delivering such material at the end of the track, light timber or plank, 10 feet in length, are easily floated and transported. The average grade of the flume is between five and six degrees. The minimum grade employed is 1 : 64, though rather too light; 1 : 33, or three feet in one hundred, is a very good grade with a fair volume of water. The flume referred to is five miles long. Cordwood is said to make the entire journey in eighteen minutes, and fifty-one cords of wood have been transported from the upper end of the flume to the place of delivery in six hours. At the end of the flume is an iron grating, having the reverse shape of the trough and inclining upward from the bottom to the upper edge of the flume. The water passes through this grating, while the wood shoots upward on it and falls over the edge of the flume to the ground, when it is piled up or loaded upon the car. This simple method of handling wood cheapens its delivery very much. No men are required, excepting those who supply the wood to the flume at the upper end, and those who receive and pile it at the other end.

Along the course of the flume there are feeding streams, brought in from side-cañons, at intervals of one or two miles, to increase the supply of water and compensate for the wastage occasioned by leaks or overrunning.

In some of the steeper side-cañons there are dry shoots, or similar flumes without water, used as feeders to that just described, the inclination being sufficient to allow the material to slide by the force of gravity alone. By this means wood is easily delivered from points where wagon roads would be impracticable.

place where cut to the flume, about $1 75 on the average; so that the total cost of delivery at the end of the flume or railroad track is covered by $4 50. Allowing $2 per cord for transportation thence to Virginia, and it may there be sold profitably at a price from twenty-five to fifty per cent. less than that ruling hitherto, which, of late years, has averaged about $16 per cord. A similar reduction may be expected in the costs of timber and lumber.

The cost of transportation of ore from the mines to the river mills has been of late years between $3 and $4, sometimes reaching $5 per ton, during the season for bad roads. Railroad transportation will reduce this, probably, to something between $1 and $2 per ton.

The costs of mining the deposits of low-grade ore will not only be lessened by the means just referred to but, probably, still further reduced by the greater accessibility of the ore-bodies and the ease with which the ore can be extracted; less careful labor being required in the assortment of the rock and in its removal to the surface. During the past few years the minimum value of ore taken to the surface from the Savage mine has been about $22 or $23 per ton, anything of less value than that, being too poor to afford a profit. By placing that limit considerably lower the quantity available for extraction will not only be largely increased, thus diminishing the costs per ton, but the labor involved will be much less, as the masses of ore are larger and require less trouble and time in selection or assortment. A corresponding reduction in milling costs may also be expected[1] by treating the ore in mills that are not only driven by water power, but that will have enlarged capacity; working much larger quantities of the poorer rock than is now worked of the richer rock in the same or less time and with consequently diminished costs; the loss of a small percentage of the value contained in a poor ore being of less importance than it is in a rich one.

Thus it is believed that these large bodies of poor quartz, hitherto unavailable, hold out much promise for the future under the conditions introduced by cheap transportation, and a reduction in the price of labor, which cannot much longer be deferred.

Sutro Tunnel.—Another enterprise, possibly destined to exercise great influence on the future welfare of the Comstock mines and the adjacent

[1]According to late intelligence received from Virginia City, the custom price of milling in some mills has been reduced to $9 per ton, including transportation of ore.

district, is the Sutro Tunnel. This scheme proposes the construction of an adit or horizontal tunnel, which, commencing in the eastern foot-hills of the range containing the lode, at a point in the valley of the Carson River and about 150 feet above the level of the stream, shall pierce the intervening country-rock with a westerly course, and, reaching the lode at a distance of about 21,000 feet from the place of beginning, cut it at a depth of nearly 2,000 feet below the outcrop.

The advantages of such a tunnel in the exploitation of the lode at a great depth have been plainly set forth by the projector of the enterprise, and consist chiefly in the facilitation of drainage and ventilation of the mines, and the transportation of ores, waste-rock, materials and men between the mines and the surface; in addition to which there would be the incidental and important advantages of opportunities afforded thereby for the further exploration, not only of the lode, but of the country lying east of it, to be passed through by the tunnel.

By affording this means of drainage, and thus relieving, as it would to a great extent, the necessity for pumping machinery and its operation, a great item in the cost of mining would be dispensed with; while the water accumulating in the vein above the level of the tunnel would be available for power for raising both water and ore from depths below.

It is proposed to construct this tunnel about 12 feet square, in section, providing it with a double railroad track for the passage of cars to and from the mines; the cars to be moved by means of a wire rope and a stationary engine at the mouth of the tunnel.

The main tunnel, to reach the lode, will have a length of about 21,000 feet; and, from the point of its intersection with the lode, lateral drifts will be run north and south in order to render the workable ground of the whole lode accessible by means of the tunnel, affording to all the mines along its length, and connected with it, the facilities of drainage, ventilation, and transportation. The aggregate length of these lateral branches will be between 15,000 and 20,000 feet.

It is proposed to sink four shafts along the course of the tunnel, from the surface to the tunnel-level, for the purpose of expediting the work by multiplying the points of attack and also to afford ventilation. The aggregate length of these proposed shafts is about 4,000 feet.

The total estimated cost of this work, comprising all labor and materials used in excavation, all machinery necessary for the shafts, with the expense of operating the same, the cost of appliances to be used at the mouth of the tunnel for the extraction of ores, and an allowance of twenty-five per cent. on the estimate for the foregoing items, to cover contingencies, is stated at $2,500,000.

This great enterprise, of which the main features have been very briefly given, was projected some years ago by Mr. Adolph Sutro, whose name it bears, and who formed a company for the purpose of carrying the plan into execution. The project was at first received with great favor, and the leading companies mining on the lode became subscribers to the stock of the tunnel company. They also entered into an agreement to pay to the said company $2 for every ton of ore extracted from any part of the mines, whether from the surface or through the tunnel, from the time that the tunnel should reach and pass through or under the ground claimed by said mines; besides other charges for the transportation of rock, materials, and men.

In 1865 the Legislature of the State of Nevada passed an act authorizing the construction of the tunnel, and granting the exclusive right of way for fifty years; and in 1866 the Congress of the United States enacted a law to aid in the construction of the tunnel, granting the right of way, with title to land and mineral veins cut by the tunnel, and other privileges, chief among which was a provision compelling all mining companies owning claims on the lode to pay to the owners of the tunnel the charges named in the contracts before referred to, into which some of them had entered, and making their titles subject to that condition.

After the passage of this act the companies that had before favorably received the tunnel project and had subscribed to the stock as well as to the contracts referred to, withdrew their support and entered into active opposition, prompted by a number of considerations, which need not be discussed here, but chief among which were the onerous conditions imposed by the contracts first made between some of the mining companies and the tunnel company and subsequently confirmed and perpetuated by Congress.

The difficulties of enlisting the requisite capital in the Eastern States and in Europe for the construction of the tunnel in a place so remote, espe-

cially enhanced by the opposing influence of the principal mining companies working the lode designed to be benefited, proved, for a long time, too great to be overcome by the most persistent efforts on the part of the projector of the scheme.

The enterprise has, therefore, until a late date, remained entirely inactive, so far as actual work in construction is concerned. Latterly, however, means have been provided in California and Nevada for the commencement of the work, and, in effect, the excavation was begun in the month of October, 1869; since which time it has, up to present writing, continued steadily in progress.

Concerning the merits of this scheme, judged only by its intrinsic worth as a means of exploitation, and not considering the conflict of interest which might arise between the owners of the tunnel and the owners of the mines, it may be said that if the lode is to be mined at such a depth as the tunnel proposes to reach, there can be no doubt but that it affords the most reasonable, if not the only profitable, method of doing so.

The demand for, or usefulness of, the tunnel depends entirely on the value of the lode in depth; and the question, now pending, as to this value is likely to be answered sooner, more fully, and at less cost by the several deep shafts, which are now being sunk from the surface downward, than it can be by any other means. These shafts vary in depth from 700 feet to 1,400 feet, the average depth of four or five of them being about 1,200 feet; to sink these four or five shafts to the tunnel-level will require less length of shafting than it is proposed to construct as auxiliary work along the line of the tunnel itself; they are already equipped with the necessary machinery, and at present rate of progress will probably reach the tunnel-level at many points before the tunnel can reach the lode at one; and some of them would need to be sunk to that level, even if the tunnel were constructed, for the purpose of connection, ventilation, and drainage. Should these shafts, with their connected prospecting works, placed as they are at intervals along the length of the lode, fail to develop any valuable bodies of ore in depth, the tunnel would not be likely to do so and there would be no necessity for its existence. On the other hand, should these explorations now in progress prove the existence of ore-bodies in depth, the tunnel would become a great desideratum if not an absolute necessity.

## SECTION III.

### REVIEW OF OPERATIONS OF LEADING MINES.

Having reviewed, in the foregoing pages, the general method of exploitation in use on the Comstock lode, the operations of some of the more important mining companies of the district will be briefly noticed.

Although those mines that have become widely known by their large products are comparatively few in number, and are situated, as has been already indicated, in disconnected groups on those portions of the lode where large and rich deposits were found, there are many others, located at either extreme or in the intermediate ground, which have thus far been unproductive, although explored with great persistence.

At the north end of the developed portion of the lode the Utah, Allen, Sierra Nevada, and the Union have spent much time and money in the development of their claims, sinking shafts to depths of several hundred feet, and exploring the ground by drifts prosecuted at various levels. All of these companies, however, excepting the Sierra Nevada, suspended operations several years ago.

Sierra Nevada.—The mine just named has been prospected to a depth of 500 or 600 feet, involving the expenditure of a large sum of money, without developing important deposits of silver ore. Its good fortune has been since found in working the surface-rock, which has proved to be rich in gold. The gold-bearing ground is not very high in value per ton, but, as it is easily extracted and cheaply milled, the work has been very profitable. Up to January 1, 1869, the company had assessed nearly $500,000, without very satisfactory results. About that time the importance of its gold-bearing surface deposits became known. A mill was erected on the property, close by the source of ore, and commenced operations, milling the rock for the gold only, without attempting to save silver. This simple process consists in amalgamation in the battery and on copper-plated tables in front of the battery, avoiding all expense for pan treatment.

During 1869 the company produced and milled 18,000 tons of rock, yielding $155,971 36, or an average of $8 66 per ton. The expenses, per

ton, were as follows: for mining, \$1 92; milling, \$3 03; incidentals; \$0 77; making a total of \$5 72, and leaving a profit of \$2 94 per ton. During the year referred to there were no assessments, and the dividends amounted to \$45,000. The mine is provided with an excellent mill of 20 stamps; also, hoisting machinery for the deeper works, not required in the present operations.

OPHIR.—South of the mines just named are situated those of the Ophir and the Mexican companies, which, in the earlier days of the development of the lode, were among the most productive. It was on this ground that the first discovery of rich silver deposits was made in 1859, on what is now the claim of the Ophir company. From the deposits of ore then discovered the Ophir and the Mexican companies, during the earlier and more prosperous years of their operations, extracted several millions of dollars. Since the exhaustion of these ore-bodies, in the upper portion of the ground, nothing of importance has been developed in depth. The Mexican mine has long been inactive, but the Ophir is, at present, vigorously at work in sinking a deep shaft in the eastern country-rock, with the purpose of exploring the lode in depth. The sinking of this shaft was begun in August, 1867, and, since that time, the working force of the company has been almost exclusively devoted to its prosecution. It has reached a depth of something over 700 feet, and, from near that point, a drift has been run toward the lode. Late in 1869 this drift, at a distance of 750 feet from the shaft, encountered an immense flow of water, which, up to the latest accounts received from the mines, prevented further progress. The drift, up to the point where the water was encountered, had passed through country-rock or unproductive vein matter. The point referred to is in or near the lode, and the old works, on a higher level, are the source of a portion of the water. When this has been exhausted it is to be hoped that some valuable discoveries will follow. Meantime some explorations are now in progress in the old works, which are reported as affording favorable results.

The new shaft of the Ophir is one of the best on the lode. It has four compartments. The pumping and hoisting machinery is well arranged and liberally provided. The pumps are 12 inches in diameter, and are driven by an engine, the cylinder of which is 18 inches diameter by 52 inches stroke.

There are three hoisting engines, two of them 10 inches in diameter, geared together and driving one shaft; the other, a new one, 18 inches in diameter by 27 inches stroke. The reels, winding flat wire rope, turn freely on the shaft, and are moved by clutches, as already indicated on a foregoing page. There are three large boilers. The whole establishment is constructed with a view to permanent and extensive operations, and is provided with the auxiliaries of smith, carpenter, and general repair shops.

The Ophir company was incorporated in April, 1860. Its claim is 1,400 feet in length. Its shares are 16,800 in number, or 12 for each foot of ground. The mine was very productive up to 1866, inclusive. The total value of the bullion produced, up to January 1, 1870, appears from available data to be $5,240,000, all of which, with the exception of, perhaps, $10,000, was obtained prior to 1867. The sum of 22 dividends, the last of which was made in March, 1864, amounted to $1,394,400; equal to $83 per share, or $996 per foot. In later years the costly works for prospecting have involved the necessity of large assessments on the stockholders. These have been as follows:

| | | | |
|---|---|---|---|
| In 1866, | $11 | per share | $184,800 00 |
| In 1867, | $11 | per share | 184,800 00 |
| In 1868, | $10 | per share | 168,000 00 |
| In 1869, | $8 | per share | 134,400 00 |
| Total | 40 | per share | 672,000 00 |

Virginia Consolidated.—South of the Ophir and Mexican the vein becomes poor, and, for aught that has thus far been developed, continues so for a distance of 1,500 or 2,000 feet. This ground, until lately, was divided among several companies, some of which performed a considerable amount of work, obtaining good ore within 200 feet of the surface. As nothing of great value was found below that depth, the work was suspended several years ago, and the property remained inactive until a consolidation of interest was effected in 1868. Under the new organization mining operations have been resumed. A shaft has been sunk in the eastern country-rock to a depth of 500 feet, and a drift toward the lode was commenced in February, 1870.

The entire work being, thus far, in the country-rock, no developments of ore-bodies have been made or looked for.

Gould and Curry.—This mine is one of the oldest locations on the lode, and has become widely known as one of the most productive. The company was organized in 1860. The nominal claim and basis of organization was 1,200 feet, but the measured length of ground, between the northern and southern boundaries, is only 921 feet. The productive ground of the Gould and Curry has thus far been confined to the southern part of the claim. The body of ore cropped out at the surface, some 300 or 400 feet from the southern boundary, and, dipping southerly, passed beyond the boundary into the Savage claim. From within these limits, about 400 feet in length, 500 feet in height, and an aggregate width of 80 or 100 feet, the Gould and Curry have extracted the whole of their large product.

Mining operations were at first carried on by means of tunnels or adits, driven in from the side of the hill, at right angles to the course of the lode, passing through the eastern country-rock, and cutting the ore-bodies in depth. Three tunnels of this description were driven at different depths, the lowest being over 2,000 feet long, and cutting the lode at a depth of 425 feet. By these means the greater part of the productive ground of the mine was worked out. In 1864 the company commenced the sinking of their deep shaft, through the eastern country-rock, partly for working the ore-ground known to exist below the level of the lowest tunnel, but chiefly to explore the mine at much greater depth. This shaft has already been described, and the costs of sinking it have been shown, on a foregoing page. The work has progressed steadily, with only few interruptions, until the present time. The depth of the shaft, at the date of the company's last report, was 1,187 feet. It is well timbered, as already described, and is in excellent condition. The pumps in the shaft are 12 inches in diameter, and extend from the adit-level, 225 feet below the surface, to the bottom of the mine. The column of each plunger pump is 200 feet high. The surface works at the shaft are amply provided with all the appurtenances of a well-equipped mine. There are four engines, two for hoisting and two for pumping, one of the latter being held in reserve as a substitute, in case of accident to the other. The principal pumping engine is a Corliss, the cylinder of which is 18 inches in diam-

eter by 36 inches stroke. The other is an ordinary engine of about the same power. The hoisting engines are smaller, one being 14 inches in diameter of cylinder by 30 inches stroke, the other 16 inches diameter by 42 inches stroke. Flat wire rope is used for hoisting. It is $3\frac{1}{2}$ inches wide by 1 inch thick. There are 4 boilers, each 26 feet long and 4 feet in diameter, and containing two flues. They are built in two independent sets of two boilers each. Only one set is in use at the same time. The consumption of wood is about six cords in twenty-four hours.

The characteristic features of the vein in this mine, and the developments made by the deep shaft, have been described at such length in the foregoing chapter that no further notice of these points is necessary here. It is sufficient to say that, up to the latest dates received, the deep shaft has revealed no ore-bodies of importance below a depth of 600 feet. During the past three years all the ore extracted from the mine has been produced by re-working the old ground, or from deposits in the upper levels that remained undiscovered in earlier days, but have since been brought to light. The old stopes, worked years ago and long since abandoned, have been reopened and worked again as virgin ground. When first mined there was a large quantity of ore that was too poor to pay then, but rich enough to afford a profit now, under reduced prices. This was then left in the mine. The ground, moreover, has since caved in, and this movement has sometimes revealed new sources of ore. Thus the old works have continued to afford ore in considerable quantities. A part of this has been extracted by contractors, who paid to the company a small price per ton, mining and milling the ore on their own account. More recently the company have carried on this work, and in 1869 did so with a very fair profit. The following tabular statement presents a summary of the operations of this company, from the beginning of their work.

*Tabular statement showing the operations of the Gould and Curry Mining Company from the date of their organization to November* 30, 1869.

| During year ending— | Tons of ore produced. | Cost per ton for mining. | Cost per ton for milling. | | Average yield per ton of ores worked. | Receipts from ores worked and sold. | Assessments. | Dividends. | Percentage of receipts paid in dividends. |
|---|---|---|---|---|---|---|---|---|---|
| | | | In company's mill. | In custom mills. | | | | | |
| November 30, 1860 | - - - | - - - | - - - | - - - | - - - | $22,004 82 | | | |
| November 30, 1861 | - - - | - - - | - - - | - - - | - - - | 44,221 41 | $166,068 00 | | |
| November 30, 1862 | 8,442 | $12 54 | - - - | $38 55 | *a* $104 50 | 858,819 32 | | | |
| November 30, 1863 | 48,743 | 12 64 | *b* $38 00 | *b* 22 30 | *a* 80 44 | 3,887,755 09 | - - - - - | $1,468,800 00 | 37.77 |
| November 30, 1864 | 64,433 | 12 00 | *b* 40 00 | *b* 26 00 | *a* 73 48 | 4,921,516 19 | - - - - - | 1,440,000 00 | 29.26 |
| November 30, 1865 | 47,217 | 10 84 | 12 93 | 20 36 | 45 41 | 2,401,060 61 | - - - - - | 618,000 00 | 25.74 |
| November 30, 1866 | 62,425 | 8 78 | 12 27 | 15 67 | 28 47 | 1,676,505 38 | - - - - - | 252,000 00 | 15.03 |
| November 30, 1867 | 24,940 | 11 35 | 13 00 | 14 34 | 24 26 | 715,101 47 | 120,000 00 | | |
| November 30, 1868 | *c* 12,153 | *d* 10 34 | - - - | 12 62 | 18 14 | 95,284 92 | | | |
| November 30, 1869 | *c* 15,879 | *d* 7 29 | - - - | 13 08 | 26 30 | 253,666 03 | 72,000 00 | | |
| | - - - | - - - | - - - | - - - | - - - | 14,875,935 24 | 358,068 00 | 3,778,800 00 | 25.55 |

NOTE *a*. During the three years of 1862, 1863, 1864, there were taken out 40½ tons of first-class ore, averaging $2,516 per ton. In 1863 there were taken out 4,812 tons of second-class ore, averaging $309 23 per ton; and in 1864 there were 8,821 tons of second-class ore, averaging $141 75. Since that time the amount of high-grade ores produced has been very small.

*b*. The difference in these costs of milling, as stated in the table, is due to the difference in the character of the ore, the higher grades requiring more expensive methods of treatment. In the case above noted the company reduced at their own mill, in 1863 and 1864, a large amount of second-class ore, at a cost of $38 and $40, sending the third-class ore to the custom mills to be treated by a less expensive process. In the following year the company's mill reduced 35,684 tons of third-class ore at a cost of $12 93 per ton.

*c*. Of the 12,153 tons, produced in 1868, only 1,229 tons were worked by the company, the yield of which was $18 14. The yield of the remainder, sold to contractors, is unknown; the average price paid to the company for a large portion of it was $6 28 per ton. Of the 15,879 tons produced in 1869, only 9,729 tons were taken out by the company, the yield of ore worked by the company being, as stated, $26 30. The 6,150 tons, taken out by contractors, yielded to the company only $1 per ton. This will explain the discrepancy apparent between the quantity of ore produced, its average yield, and the total receipt of bullion; the last item simply shows all the company's receipts from ores worked or sold, and from the treatment of tailings, sluices, &c.

*d*. The cost of $10 34 per ton in 1868 includes all dead work, prospecting, and incidental expenses, divided among the number of tons of ore produced; $7 29 per ton in 1869 is only the cost of extracting 9,729 tons on company's account; including nothing for dead-work, improvements, &c.

SAVAGE.—This mine adjoins the Gould and Curry on the south. The actual length of the claim is stated at 771 feet, although the company is organized on a basis of 800 feet, with a subdivision of 20 shares to each foot, making a total of 16,000 shares. The earlier workings of the company were confined to the northern portion of their ground, and was prosecuted by means of a shaft, sunk on the croppings, about 200 feet south of their northern boundary. At a depth of 600 feet, to which this shaft was sunk, it had already reached and passed considerably below the west wall. Following the example of the Gould and Curry, the company located their new shaft about 800 feet east of the old one, on the croppings, and about midway be-

tween the north and south boundaries. This shaft has now been sunk more than 1,000 feet, and the mining operations of the company, during later years, have been carried on entirely by this means, the old works having been abandoned. The characteristic features of the mine, the methods of mining employed, and the works established at the mouth of the shaft, have been already described. The following statements present a general summary of the company's operations from their beginning.

*Tabular statement showing the operations of the Savage Mining Company from April,* 1863, *to July* 1, 1869.

| | Tons of ore extracted. | Tons of ore reduced. | Cost per ton for mining. | Cost per ton for milling. | Average yield per ton. | Receipts from ores worked and sold. | Assessments. | Dividends. | Percentage of receipts paid in dividends. |
|---|---|---|---|---|---|---|---|---|---|
| From April, 1863, to July 1, 1865 | 81,183 | 81,183 | - - | - - | $44 35 | $3,600,709 26 | $108,000 | $800,000 | 22.22 |
| During year ending July 1, 1866 | 30,653 | 29,535 | $18 06 | $16 74 | 44 14 | 1,303,852 91 | 80,000 | | |
| During year ending July 1, 1867 | 70,721 | 69,430 | 7 91 | 14 04 | 41 97 | 2,914,164 37 | - - - | 1,120,000 | 38.43 |
| During year ending July 1, 1868 | 87,342 | 84,627 | 7 21 | 13 74 | 40 84 | 3,506,082 97 | - - - | 1,560,000 | 44.50 |
| During year ending July 1, 1869 | 69,287 | 55,479 | 8 90 | 12 22 | 34 87 | 1,950,550 92 | - - - | 728,000 | 37.32 |
| Total to July 1, 1869 - - - | 339,186 | 320,254 | - - | - - | - - | 13,275,360 43 | 188,000 | 4,208,000 | 31.62 |

It may be observed in explanation of the high costs of mining in 1866, that the mine was making large outlays at that time in prospecting work and improvements, the cost for which, per ton, is included in the statement. It may be also remarked that during the last two years the company have sold a considerable amount of ore to outside parties; that is, have permitted contractors to work in the old mine, paying a royalty of $1 per ton on ore extracted. The ore thus taken out in 1869 amounted to more than 15,000 tons. The yield, stated in the column, applies only to the ore worked on company's account, but the item of receipts includes product of ores sold. Elsewhere will be found tables showing the classification of the ores produced, detailed statements of cost, &c.

The present condition of the mine is less prosperous than it has been during two or three years past. The known bodies of ore have been well nigh exhausted. The sinking of the shaft is still vigorously carried on as

well as the prospecting of the ground in depth; but if ore-bodies exist there they have yet to be discovered. Since the beginning of 1870 an assessment of $10 per share has been called.

HALE AND NORCROSS.—This mine is situated next south of the Savage. Its claim covers 400 feet along the length of the lode and the present organization of the company is based on a subdivision of each foot in 20 shares. Operations were begun in 1861 or 1862. A shaft was located near the croppings of the lode and was sunk vertically until striking the west wall at a depth of 535 feet, when its direction was changed so as to follow the inclination of the foot-wall of the vein, reaching in that manner a vertical depth of 780 feet. During the progress of this work exploring drifts were made from the shaft at various depths, and though the ground in the upper levels was carefully and persistently prospected, no important bodies of ore were found until attaining a depth of about 500 feet. Here, late in 1865, a very valuable deposit was discovered, and the company then entered upon a very prosperous career. In 1866 a new shaft, located in the eastern country-rock, and resembling in general features the shafts of the Gould and Curry and the Savage, was begun and has since served in the development and exploitation of the deeper portion of the mine. It is now between 1,000 and 1,100 feet deep. The present sources of ore in the mine are not confined to the lower levels, as the old works are still mined through the shaft that was sunk on the croppings, and, in the summer of 1869, were contributing largely to the general product. The ore-bodies of the mine and their mode of occurrence have been noticed in the foregoing chapter. The deep shaft of this mine resembles those already described but has only three compartments. One for pumping, is 5 feet square; the other two, for hoisting, are 4 by 5 feet, in the clear. The pumping and hoisting works have been already referred to. Their method of arrangement is shown on Plate XIII.

The pumps are 11 inches in diameter. The pumping engine has a cylinder 20 inches in diameter by 48 inches stroke. The hoisting engine has an 18-inch cylinder with 30 inches stroke. The winding reels are 10 feet in diameter and have a winding capacity of 2,300 feet of flat steel rope, 4 inches wide by $\frac{3}{8}$ of an inch thick. The method of controlling the reels

has been already shown. At the old shaft there are also hoisting works, in which friction-gearing is employed.

The operations of this company are partially set forth in the following statement, from which it will be seen that previous to the discovery of their ore in 1865, the assessments had amounted to $350,000. The writer has no knowledge of the product during that period. The reserves of the mine falling off in 1868, assessments were again required, but dividends were resumed in 1869.

*Tabular statement showing the operations of the Hale and Norcross Mining Company.*

| | Tons of ore extracted. | Tons of ore reduced. | Cost per ton for mining. | Cost per ton for milling. | Average yield per ton. | Receipts from ores worked and sold. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|---|---|
| Previous to 1866 | - - - | - - - | - - | - - | - - | - - - - | $350,000 | |
| During year ending March 20, 1867 | 29,401 | 28,635 | $9 08 | $14 26 | $47 32 | $1,358,084 89 | - - - | $490,000 |
| During year ending February 29, 1868 | 25,432 | 25,332 | - - | 14 23 | 34 14 | 865,925 45 | 60,000 | 300,000 |
| During year ending February 28, 1869 | 16,803 | 17,081 | *a* 9 02 | 13 11 | 23 89 | 395,691 77 | 200,000 | |
| During year ending February 28, 1870 | 51,980 | 45,441 | *a* 5 14 | 12 49 | 27 13 | 1,232,929 01 | - - - | 192,000 |
| Total | 123,616 | 116,489 | - - | - - | - - | 3,852,631 12 | 610,000 | 982,000 |

*a* Paid for labor per ton of ore extracted.

Chollar-Potosi.—This mine adjoins the Hale and Norcross on the south. The length of the claim belonging to this company is stated at 1,434 feet. The number of shares in the company is 28,000. The present organization is the result of the consolidation of two or more claims, the chief of which were originally known as the Chollar and the Potosi. The Chollar was originally located as a square claim on the surface, measuring about 1,400 feet along the length of the lode, by about 400 feet in width; the Potosi located a similar claim, of equal length, parallel to and lying east of the Chollar. At that time the structure of the vein, the form and dip of the ore-bodies, and their relations to each other were not at all understood. The body of ore discovered on the Potosi claim was found to be dipping to the west, and by sinking upon it the company passed beyond the boundary, determined by the square surface claim, into the ground of the Chollar. A suit was instituted

and gained by the latter company to restrain the Potosi from encroaching upon the ground of the Chollar. In process of further developments the ore-bodies took an easterly pitch, when the Chollar, in its turn, began to encroach upon the Potosi. This gave rise to further litigation, in which a large amount of money was expended, with the final result of a consolidation of interests of the two companies, forming the present Chollar-Potosi.

The two companies previous to consolidation found large and valuable bodies of ore in the upper portion of the lode, from which a large amount of bullion was produced. The ground was worked by means of shafts on each claim, and adits driven in from surface, cutting the vein at a depth of 200 or 300 feet. The productive bodies of quartz, however, did not extend in depth below 450 or 500 feet. Since the consolidation of the two companies, the Chollar-Potosi have extracted from these upper levels a large amount of ore, much of it being of a low grade. This work is still in progress, and during 1869 was being carried on with profit.

Meantime, while the productive portion of the mine is confined to the upper levels, the company have been steadily engaged in prospecting their ground in depth by means of a large shaft, which descends vertically 913 feet, at which depth the west wall of the lode is encountered, and thence the shaft inclines at an angle of 45°, following nearly the inclination of the vein. The depth attained in the summer of 1869 was 1,240 feet, measured vertically. No ore-bodies have yet been developed by this work below the levels reached by the operations of the old mine.

The shaft is of the same general character as those already mentioned. The method of timbering has been already shown. The hoisting and pumping works that were formerly established at this shaft were provided on an ample scale for extended operations; but the inclosing buildings were destroyed by fire in the summer of 1869. The damage was being repaired at the date of the writer's visit, but the hoisting machinery had not then been replaced.

The following tabular statement shows the extent of the company's operations during three years, according to the data furnished in their published reports. The ore statements for years previous to May 31, 1866, are

wanting; but the table shows the sum total of the receipts from ore, the assessments and dividends, from the date of organization to May 31, 1869.

*Statement showing the operations of the Chollar-Potosi Mining Company during three years ending May* 31, 1869.

| | Tons of ore extracted. | Tons of ore reduced. | *a* Cost per ton for mining. | Cost per ton for milling. | Average yield per ton. | Receipts from ores worked and sold. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|---|---|
| Previous to May 31, 1866 - - - | - - - | - - - | - - | - - | - - | $917,981 56 | $280,000 | |
| During year ending May 31, 1867 | 57,799 | 57,799 | $6 39 | $14 97 | $25 73 | 1,348,323 13 | - - - | $70,000 |
| During year ending May 31, 1868 | 70,331 | *b* 77,957 | 6 93 | 14 75 | 24 14 | 1,905,421 49 | 182,000 | 350,000 |
| During year ending May 31, 1869 | 44,900 | *b* 46,867 | 7 94 | 13 15 | 23 70 | 1,185,141 92 | - - - | *c* 42,000 |
| Total - - - - - - - - - - | 173,030 | 182,623 | - - | - - | - - | 5,356,868 10 | 462,000 | *c* 462,000 |

*a*. This cost includes dead work and prospecting in new shaft. See pages 155 and 156.
*b*. Including some ore taken out by contractors on tribute.
*c*. Later in same year, 1869, six other dividends, amounting to $252,000, or $9 per share, were paid to stockholders.

The Chollar-Potosi is the southernmost of the mines situated on the Virginia group of bonanzas. Beyond it, in a southerly direction, the ground becomes poor and continues so for a distance of 1,000 or 1,500 feet. Within these limits is situated the claim of the Bullion company, the southern neighbor of the Chollar-Potosi. This mine has been most persistently explored without any very encouraging result. The claim is 940 feet in length, measured on the course of the lode. A shaft has been sunk upon it, vertically, until reaching the west wall at a depth of about 800 feet, and then inclined with the vein several hundred feet further, so that the whole vertical depth of the explorations is about 1,200 or 1,300 feet. Prospecting drifts have been made at successive levels, developing large bodies of quartz, but generally too poor to pay for extraction. During the several years that it has been worked the product has been practically nothing; according to the statements of the treasurer of the company it does not exceed $1,000.

In 1868 the assessments were $100,000; in 1869 they were $67,500; and the total amount of assessments is more than $1,000,000. Operations were still in progress in the summer of 1869; but they have recently been suspended, according to newspaper reports.

Imperial and Empire.—The next occurrence of rich ore-bodies begins not far south of the Bullion mine, and is known as the Gold Hill group. Within a length of 1,000 feet are situated some 15 or 20 claims, most of them very short, from which their owners extracted, in early days, a very large amount of bullion. From some claims, not exeeeding 20 or 30 feet in length, one of them being only 10 feet long, a very large monthly revenue was obtained. An accurate record of this production is not in the writer's possession, and probably does not exist. Chief among the mines of this group are the Imperial and Empire, of whose operations a statement will be found further on. Both of these companies, although working very short claims, have been very productive and profitable, having disbursed large dividends, without having, until recently, called assessments. The Alpha, Challenge, Confidence, and others of the group, have also been prominent in times past.

The productive ore-bodies of these mines, and those of their neighbors belonging to the same group, all occurred within 500 or 600 feet of the surface. The richest of them were worked out long ago. During the past two or three years the old ground has been reworked; deposits of ore that were too poor to pay in former times, have been mined, and thus the production has been sustained, though on a much diminished and less profitable scale.

The chief hope for the future of all the mines of this group is based on the work of exploration, now being carried on in depth by a vertical shaft, sunk jointly by the Imperial and Empire, but also designed for the development of the neighboring claims. This shaft, located like the deep shafts of the other large mines, in the eastern country-rock, has reached a depth of over 1,100 feet, and has cut the vein at about that distance from the surface. No important developments of ore have yet been made by this work, but it is still vigorously prosecuted. The shaft is similar in kind to those already described. It has four compartments. It is 28 feet 4 inches long by 5 feet wide, for 600 feet of depth, where the size is contracted to 18 feet of length, divided into three compartments. The machinery for pumping and hoisting is liberally provided. There are two hoisting engines, having cylinders 16 inches in diameter and 36 inches stroke. These both drive one shaft, on

which the winding reels are operated by means of clutches and brakes, as already described. The water is removed from the mine by means of vessels, raised and lowered like the cages, and operated by the same machinery. A pumping engine is provided, but the pumps are not yet in place.

There are four tubular boilers, 16 feet long and 52 inches in diameter. The whole of this establishment is inclosed in a large building, with which are connected carpenter and smith shops for all necessary work of construction and repair. The total cost of sinking this shaft, and establishing the surface works appertaining to it, and conducting the explorations in connection with the same, amounts already, according to the reports of the two companies, to about $400,000. The following statements present a summary of the operations of the two companies, Imperial and Empire.

*Statement showing the operations of the Imperial Mining Company from date of their organization to May* 31, 1869.

| | Tons of ore worked. | *a* Approximate cost per ton for mining. | *d* Approximate cost per ton for milling. | Average yield per ton. | Receipts from ores worked and sold. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|---|
| Previous to May 31, 1864 . . . . | . . . | . . . | . . . | . . . | $640,369 43 | $50,000 00 | $67,500 00 |
| During year ending May 31, 1865 . | 28,237 | $5 37 | $11 50 | $30 26 | 854,630 56 | . . . . . | 220,000 00 |
| During year ending May 31, 1866 . | 35,182 | 5 27 | 10 00 | 29 97 | 1,019,275 92 | . . . . . | 240,000 00 |
| During year ending May 31, 1867 . | 40,878 | 4 36 | 9 00 | 25 93 | 1,060,054 10 | . . . . . | 396,000 00 |
| During year ending May 31, 1868 . | 41,234 | 4 96 | 9 66 | 21 75 | 897,108 02 | . . . . . | 120,000 00 |
| During year ending May 31, 1869 . | 45,172 | 4 73 | 7 81 | 13 35 | 603,146 42 | 100,000 00 | 24,000 00 |
| | 189,724 | . . . | . . . | . . . | *b* 5,074,584 45 | *c* 150,000 00 | 1,067,500 00 |

*a*. Costs of mining are only approximately stated. They do not include the outlay for new shaft, prospecting, &c. A somewhat more detailed statement has been already given on page 152.

*b*. This sum is from ores worked and sold, not including revenue from other sources, such as cash received for working rock in company's mill for outside parties. The total receipts, including assessments, amount to $5,365,704 03.

*c*. Additional assessments, amounting to $100,000 were subsequently called during 1869.

*d*. Includes hauling the ore from mine to mill.

*Statement showing the operations of the Empire Mill and Mining Company from their commencement to December*, 1869.

| | a Tons of ore extracted by the company. | Tons of ore worked by the company. | Average yield per ton of ore worked. | b Receipts from ores worked and sold. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|
| Previous to December, 1864 | . . . | . . . | . . . | $1,043,720 48 | . . . . | $288,000 00 |
| During year ending December, 1865 | 22,870 | 16,000 | $30 28 | 508,192 22 | . . . . | 120,000 00 |
| During year ending December, 1866 | 22,923 | 17,995 | 21 86 | 414,139 87 | . . . . | 32,400 00 |
| During year ending December, 1867 | 15,027 | 11,779 | 21 92 | 294,583 60 | . . . . | 49,200 00 |
| During year ending December, 1868 | 11,028 | 10,724 | 20 00 | 218,703 77 | . . . . | . . . . . |
| During year ending December, 1869 | . . . | . . . | . . . | c 150,000 00 | $30,000 00 | . . . . . |
| | . . . | . . . | . . . | 2,629,339 94 | 30,000 00 | 489,600 00 |

*a*. Not including ores taken out by other parties, purchasing of the company.
*b*. Not including revenue derived from hoisting ores from adjoining claims, and from some other sources.
*c*. Estimated; the company having published no report for the year referred to.
NOTE.—The costs of mining and milling are not definitely stated; as an average, the whole expense, including everything connected with the working of the mine and the management of the business, amounts to about $20 00 per ton of ore.

The principal group of mines south of the last named, comprises the Yellow Jacket, Kentuck, and Crown Point. These are intimately related to each other. Their ore-bodies form one simple group or system, and the mines, working at about an equal depth, one with the other, are all connected together in their lower levels. The Kentuck, owning but a short strip of ground between the Yellow Jacket and Crown Point, is worked chiefly through the shafts of its neighbors.

The bodies of ore developed in these mines, and their relations to each other, have been already discussed. A brief statement of the operations of the several companies will therefore suffice for the purpose of this review.

YELLOW JACKET.—The ground of the Yellow Jacket mine is 943 feet in length, measured on the course of the lode, but the organization of the company is based on a length of 1,200 feet, each foot, at least until recently, representing one share of the stock.[1]

The ore-bearing ground of the Yellow Jacket is in two parts, one of which is in the northern, the other in the southern portion of the claim, the intermediate ground, at least in the upper levels, being poor. The northern

[1] If the writer be correctly informed, each foot now represents a larger number of shares, probably 20.

portion, known as the north mine, was worked in the earlier days of the company's operations, and proved to be rich and profitable to a depth of 500 or 600 feet. The known resources of this part of the claim having been exhausted several years ago, the work was transferred to the south mine, adjoining the Kentuck. A deep shaft has been sunk, through which the extensive operations of the mine have been almost entirely carried on during several years. This shaft has reached a depth of over 1,000 feet, developing large bodies of ore-bearing quartz, which, though not very high in value, is said to afford a profit. During the summer of 1869 the lower levels of this mine were extended to the north, below the north mine, making connection with the old works, and developing in them new sources of ore, which promise to be of great importance. The mine is well provided with pumping, hoisting, and other required machinery, both at the older and newer shafts. The latter are the most important. They comprise two hoisting engines, each 14 inches in diameter of cylinder, and both geared together to drive one shaft. Friction-gearing is employed for winding, there being three drums, one for each hoisting compartment of the mine-shaft. The depth of this shaft is now so great that it is intended to substitute cog-gearing, similar to that used by the Hale and Norcross, in the place of the friction-gearing. The new machinery for this purpose was on the ground in September, 1869, but not then put in position. The pumping engine is a Corliss, 18 inches in diameter and 36 inches stroke. The pumps are 11 inches in diameter, raising the water to within 300 feet of the surface, where it flows off by an adit. The shaft has four compartments; it is 24 feet long by 5 feet wide, in the clear. The establishment is provided with carpenter and smith shops, and other necessary appurtenances. The company own a large mill on the Carson River, about 10 miles from the mine, which not only crushes the ores produced by the mine, but has sometimes been an important source of revenue by crushing custom ores.

The operations of this company were greatly retarded in 1869, by a disastrous fire that broke out in the lower levels, causing great loss of life and damage to the property. A brief account of this will be found further on.

The following table presents a partial statement of the company's operations during several years past:

*Statement of operations of the Yellow Jacket Mining Company.*

| | Tons of ore produced. | Approximate cost per ton for all ordinary expenses. | Average yield per ton. | Receipts from ores worked and sold. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|
| Previous to August 1, 1864 | - - | - - | - - | *d* $1,500,000 00 | Inclu'd below | $330,000 |
| August 1, 1864, to July 1, 1865 | 49,013 | $23 83 | $33 06 | 1,528,790 54 | $300,000 | |
| During year ending July 1, 1866 | 55,006 | 23 63 | 32 51 | *a* 1,695,228 20 | 300,000 | |
| During year ending July 1, 1867 | 84,340 | 24 56 | 31 73 | *b* 2,677,447 66 | - - - | 600,000 |
| During year ending July 1, 1868 | 34,718 | 29 75 | 19 50 | *c* 682,003 90 | 390,000 | 90,000 |
| From July 1, 1868, to January 1, 1870, eighteen months. | - - | - - | - - | *d* 2,500,000 00 | 360,000 | 720,000 |
| | - - | - - | - - | 10,583,470 30 | 1,350,000 | 1,740,000 |

*a*. Not including $77,500 derived from other sources, chiefly milling and hoisting.
*b*. Not including $84,375 derived from other sources, chiefly milling and hoisting.
*c*. Not including $52,494 derived from other sources, chiefly milling and hoisting.
*d*. Estimated.

KENTUCK.—The Kentuck mine, adjoining the Yellow Jacket on the south, and situated between the last-named and the Crown Point, holds about 95 feet of ground, measured on the course of the lode. It has been one of the most successful and profitable mines on the vein, having paid to the shareholders over $1,100,000 before collecting a dollar of assessments. The company was incorporated on the 22d of August, 1865. Money was borrowed to the extent of $20,000 to open the mine, and an assessment was called to discharge the debt, but, before it was collected, the prospects of the mine were so encouraging that the call was rescinded and the loan paid from the product obtained. The first ore was produced from the mine in January, 1866, having been struck at a depth of 200 feet from the surface. Its product during the few succeeding months was small, but later in the year a rich body of ore was developed on the 460-foot level, and in September, 1866, the first dividend was paid. The aggregate amount of dividends up to the date of the last report, November, 1869, is $1,142,000. The work of the mine suffered great hindrance by the fire already referred to and the first assessment of $40,000 was subsequently

called. The upper levels of the mine were worked by a shaft sunk by the company to a depth of about 700 feet. Its lower levels are worked through the shafts of the Yellow Jacket and Crown Point. The following table exhibits the operations of the company from the outset to November, 1869.

*Statement showing operations of the Kentuck Mining Company from their commencement to November* 1, 1869.

| | Tons of ore produced. | Average cost per ton for mining. | Average cost per ton for milling. | *b* Average yield per ton. | Receipts from ores worked, including premium on bullion. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|---|
| From November 1, 1865, to May 1, 1867 | - - | - - | - - | - - | *a* $852,803 30 | - - | $257,000 |
| From May 1, 1867, to November 1, 1867 | 15,835 | $9 23 | $15 49 | $43 86 | 721,844 05 | - - | 335,000 |
| During year ending November 1, 1868 . | 31,390 | 9 81 | 14 28 | 40 06 | 1,259,717 99 | - - | 450,000 |
| During year ending November 1, 1869 . | 26,866 | 8 67 | 13 95 | 29 99 | 806,696 66 | 40,000 | 100,000 |
| | - - | - - | - - | - - | 3,641,062 00 | 40,000 | 1,142,000 |

*a*. In addition to this sum, $63,124 10 was derived from other sources.
*b*. Not including premium on bullion.

Crown Point.—This has been one of the successful and profitable mines of the Comstock lode, as the following statement of its operations will clearly show. During the latter part of 1869 its product fell off as the known deposits of ore were nearly exhausted, but the late developments in the lowest level of the Yellow Jacket promise much for the future of the Crown Point. The mine is well worked and thoroughly equipped with the necessary machinery for extended operations. Its hoisting and pumping works are among the best in the district. The method of arrangement of this machinery is shown on Plate XII. There are three engines, two for hoisting and one for pumping, operating the winding and pumping machinery as already explained. The shaft is sunk vertically in three compartments, and is over 1,100 feet deep. The methods of work in this mine are generally the same as those already described. The company own two mills for the treatment of their ores. The following table sets forth a statement of their operations from the outset.

*Statement showing operations of the Crown Point Mining Company from their commencement to May* 1, 1869.

| | Tons of ore produced. | Approximate cost per ton for— | | Average yield of ores worked per ton. | Receipts from ores worked and sold, including premium on bullion. | Assessments. | Dividends. |
|---|---|---|---|---|---|---|---|
| | | Mining. | Milling. | | | | |
| Previous to June 1, 1864 | - - | - - | - - | - - | $36,572 08 | $95,370 | |
| From June 1, 1864, to May 1, 1865 | 3,766 | - - | $12 13 | $35 60 | 134,080 92 | | |
| During year ending May 1, 1866 | 18,259 | $8 97 | 14 00 | 37 73 | 700,565 56 | 60,000 | $78,000 |
| During year ending May 1, 1867 | 34,750 | 7 50 | 13 35 | 35 91 | 1,265,155 29 | - - | 372,000 |
| During year ending May 1, 1868 | 25,964 | 9 85 | 13 00 | 33 35 | 873,998 49 | 60,000 | 48,000 |
| During year ending May 1, 1869 | 25,833 | 9 80 | 11 66 | 32 73 | 851,559 00 | 90,000 | 360,000 |
| | - - | - - | - - | - - | 3,861,931 34 | 305,370 | 858,000 |

The fire already referred to as having occurred in the Yellow Jacket, Kentuck, and Crown Point mines is one of the most remarkable disasters in the history of mining in this country. Although originating in the Yellow Jacket the terrible effects were shared by the adjoining mines, and the loss of life was much greater in the Crown Point than elsewhere, owing to the fact that the draught of air passing down the Yellow Jacket shaft through the Kentuck levels and up the Crown Point shaft, filled those mines and all their avenues of escape with a dense volume of smoke which, instantly suffocated the unfortunate men who were overtaken by it. The origin of the fire, although not positively known, appears from the report of Mr. J. P. Jones, superintendent of the Crown Point mine, to have been on the 800-foot level of the Yellow Jacket mine and near the south boundary line of that property; and it is believed to be probable that when the night men left the mine at 4 o'clock in the morning, one of them thoughtlessly left a lighted candle sticking in a splintered and resinous stick of timber, which, becoming ignited, communicated the fire to the timbers adjoining. It is further supposed that the fire burned slowly at first, creeping along the level toward a door dividing the Yellow Jacket from the Kentuck, which door, being closed, checked the circulation of air and caused a slow combustion; but as soon as the door burned from its hinges the smouldering mass of timber burst into flame, while the great volume of smoke and gas swept through the mines suddenly, overwhelming the

laborers, who were warned too late of its approach. It is only necessary to imagine a mass of timbering similar to that of which a view is given on Plate V, but filling spaces from twenty to forty feet wide and several hundred feet in length and depth, dry and resinous as it often is in some mines, and subjected to a powerful draught of air, to understand how great a conflagration may be possible in the underground chambers.

According to Mr. Jones's report the fire was first discovered at 7 o'clock in the morning of April 7. The night-force had been withdrawn from the mine, and the greater part of the day-men had been lowered to their stations, when the smell of fire was detected in the Crown Point mine at the 700-foot station. A signal called the cage to the 800-foot station where many workmen had collected in alarm. The cage was filled with men and raised to the surface with the greatest possible speed, and the work of removal continued until five loads of workmen were safely extracted from the 600-foot, 700-foot, and 800-foot levels. A cage was sent down to the 1000-foot level, in response to a signal of alarm from that point. On descending, however, none of the workmen employed there were found, as they had left the station in the attempt to climb up the pump-shaft, where their bodies were afterward found. The cages were kept running for many hours from station to station and to the surface in the hope that some one might find his way from the chambers of the mine to the shaft, and thus be saved, but it soon became evident that all still remaining below had perished. In the Crown Point 25 lives were lost; in the Kentuck, 7; and in the Yellow Jacket, 5. The fire increased until 2 o'clock p. m., from which time until 11 o'clock it seemed to abate, when a partial exploration through the 900-foot level was made, resulting in the recovery of 13 bodies. On the following morning 9 other bodies were recovered. On the following day, the 9th, the fire again increasing, and no hope remaining of rescuing any of the men still in the mines, the three shafts of the several companies were tightly sealed up and a continuous current of steam was forced down each shaft, in the hope of thus extinguishing the fire. This was continued several days, with occasional interruption for the purpose of examination. On the 26th the shafts were opened and it became possible to go into the mines and contend against the fire with

water and steam, in the immediate neighborhood of the smouldering timbers. Nearly a year has now elapsed since the fire begun, and, at latest accounts, it is not yet extinguished. It is, however, confined to portions of the Yellow Jacket, and these have been closed up by tightly sealing all drifts or passages communicating between the burning districts and the shafts, thus cutting off the supply of air from the locality of the fire, and making it possible to resume mining work in the other parts of the mine.

When visited by the writer in the following October, the regular work of the mines was again in progress. The burning or smouldering portion of the mine was sealed up as just described, and the extraction of ore was being carried on in stopes immediately below. At one point, only four feet of rock divided the working stopes from the chambers above, in which were confined the smoke and gas resulting from the slow combustion of the timber.

Belcher.—The Belcher and the Overman are the most prominent mines south of the Crown Point. The first named, including the Segregated Belcher, covers an extent of 1,000 feet of the lode. In 1864 the Belcher had a productive body of ore, from which a large amount of bullion was obtained and handsome dividends were paid. This deposit was 200 or 300 feet long, but did not continue beyond a depth of 300 feet. The mine has been steadily worked, and is still being developed with results that are encouraging without being quite satisfactory. During the days of prosperity the company paid, from June, 1864, to June, 1865, dividends amounting to $421,200. The total product up to January 1, 1870, appears to be $1,570,370, of which only $20,000 were produced during the last two years. The assessments in 1868 were $104,000, and in 1869, $109,200; the sum of assessments is $668,720, of which it is said that $130,000 was collected of the shareholders, not in cash, but in the form of company's stock, and was devoted to settling some matters in litigation.

Overman.—The Overman adjoins the Segregated Belcher on the south and owns 1,200 feet. The mine has been worked several years, and is developed to a depth of over 700 feet. It possesses large bodies of ore that have, however, a low value and cannot afford a large margin of profit. Nevertheless, with the reduction in the cost of transportation and milling which the railroad is effecting, there should be a fair promise in the future for this mine.

The average value of the ore is generally stated at $20 to $25 per ton. The only positive information on this point in the possession of the writer is based on the operations of the mine from July 7, 1869, to January 10, 1870, when, according to the official accounts, there were 11,392 tons of ore crushed, producing $166,696 04, or an average, per ton, of $14 63. The following is a statement of the assessments called by this company and bullion produced by the mine during four years past:[1]

| | Assessments. | Bullion. |
|---|---|---|
| In 1866 - - - - - - - - - - | $208,000 | $27,953 |
| In 1867 - - - - - - - - - - | 32,000 | 192,318 |
| In 1868 - - - - - - - - - - | 176,000 | 352,590 |
| In 1869 - - - - - - - - - - | 128,000 | 336,455 |
| | 544,000 | 909,316 |

The following table presents a summary of the statements given in this review:

*Summary of foregoing tables, showing the value of the Ore Products, the amount of Assessments, and Dividends of leading companies working on the Comstock lode.*

| | Receipts from ores worked and sold. | Assessments. | Dividends. | |
|---|---|---|---|---|
| Ophir - - - - - - | $5,240,000 00 | $672,000 | $1,394,400 | To January 1, 1870. |
| Gould and Curry - - | 14,875,935 24 | 358,068 | 3,778,800 | To November 30, 1869. |
| Savage - - - - - - | 13,275,360 43 | 188,000 | 4,208,000 | To July 1, 1869. |
| Hale and Norcross - - | *b* 3,852,631 12 | 610,000 | 982,000 | To February 1, 1870. |
| Chollar-Potosi - - - | 5,356,868 10 | 462,000 | 462,000 | To May 31, 1869. |
| Imperial - - - - - | 5,074,584 45 | 150,000 | 1,067,500 | To May 31, 1869. |
| Empire - - - - - | 2,629,339 94 | 30,000 | 489,600 | To December 1, 1869. |
| Yellow Jacket *a* - - - | 10,583,470 30 | 1,350,000 | 1,740,000 | To January 1, 1870. |
| Kentuck - - - - - | 3,641,062 00 | 40,000 | 1,142,000 | To November 1, 1869. |
| Crown Point - - - | 3,861,931 00 | 305,370 | 858,000 | To May 1, 1869. |
| Belcher - - - - - | 1,570,370 00 | 668,720 | 421,200 | To December 31, 1869. |
| Overman - - - - - | 909,316 00 | 544,000 | | To December 31, 1869. |
| | *c* 70,871,138 58 | 5,378,158 | 16,543,500 | |

*a* Partially estimated.

*b* The product of this mine previous to March, 1866, is not included.

*c* The products of the Mexican mine and of many of the small but very rich claims of Gold Hill are not included here; for a more complete statement of the bullion product of the lode see pages 189 and 190.

[1] Commercial Herald and Market Review.

OUTSIDE MINES.—There are a number of mines in the Washoe region that, being located on other veins than the Comstock, are generally classed as "outside." They are on various ledges that have from time to time been discovered, partly prospected and developed, and, in most cases, again abandoned or neglected on account of the low grade of ore produced and the high cost of working. Among them, however, are several that have been persistently worked, and of these a still smaller number have established a claim to an important place in the list of successful and profitable mining enterprises. The Occidental is one of the most prominent of this class, located on a large ledge, between one and two miles east of the Comstock, nearly parallel to the last-named vein in trend, and dipping also to the eastward at an angle of about 45°. This vein is a mass of limestone and quartz from 20 to 40 feet wide. The silver-bearing mineral, resembling in most respects that of the Comstock, is associated with the calcareous and silicious gangue, and thus far the limestone has been the richer of the two. The pay-seam is from 6 to 12 feet wide. The mine is worked for over 1,200 feet in length and 300 or 400 feet deep. It is opened and developed entirely by tunnels, and a lower tunnel is now in course of being driven, which, when completed, will be 1,600 feet long, cutting the lode at a depth of 800 feet. The company own a mill near Dayton, and are now building a new and large one near the mine. The yield of the ore is stated at $12 to $16 per ton. In the summer of 1869 the mine was producing about 25 tons per day. The writer is not able to give any accurate statements concerning the total production of this mine. The company has paid one dividend of $20,000; and, if the writer be correctly informed, has never levied any assessment.

Further north, and probably the same vein under a different name, is the Monte Christo lode, crossing Six-Mile Cañon near the Gould and Curry Mill. This lode is developed to a much less extent.

The Lady Bryan, one of the most important and best developed of the outside mines, lies further east, probably on a different lode, in the so-called Flowery District. This mine has been worked several years with varying success; once entirely abandoned, the machinery was removed and the property sold for a trifling sum; then revived by other parties and now working

vigorously again with fair prospects. The lode strikes north 30° east, true, and dips easterly 45° to 55°. The croppings are very large and the vein consists chiefly of quartz. The surface works yielded a large amount of ore of low grade. The underground developments had reached a depth of about 200 feet in October, 1869. A shaft, having three compartments, was in progress. The mine is provided with excellent hoisting and pumping works; and a new 10-stamp mill was built last year close by the shaft. The mill is furnished with four McCone pans and two large settlers. It can crush and amalgamate about 20 tons per day. The rock is said to yield $30 per ton. The assessments of this company amounted to $15,000 in 1866; and in 1868 to $150,000. Accounts of its production are not in the writer's possession.

Among other promising mines is the Twin, or, as it is more recently called, the Hope, working on a narrow gold-bearing vein near Silver City. It is said that this vein, although worked on a limited scale, has yielded fair profits to its owners. A new mill, containing stamps that are to be driven by the direct action of steam upon each stamp-stem, is in process of construction.

Below Silver City, on the road to Carson, is the Spring Valley district, the scene of much exploration several years ago, and containing some ledges to whose prospective value the railroad may add largely.

Bullion Product of the Comstock.—The total yield of the Comstock lode from the date of its discovery in 1859, to December 31, 1869, is probably not less than $100,000,000. In 1859 and 1860, little was exported, and that chiefly in the form of rich ores that were sent to Europe. In 1862 and 1863, the bullion production increased rapidly, reaching its maximum rate in 1864 and 1865. The following statement, prepared chiefly from data furnished by the Commercial Herald and Market Review, of San Francisco, shows the annual production for nine years. As this statement is chiefly based upon the products of prominent mines, whose operations are well known, it is safe to assume that enough more has been obtained from sources not included in this account to swell the total to $100,000,000.

| | |
|---|---|
| 1860 | $100,000 |
| 1861 | 2,000,000 |
| 1862 | 6,000,000 |
| 1863 | 12,400,000 |
| 1864 | 16,000,000 |
| 1865 | 16,000,000 |
| 1866 | 11,739,100 |
| 1867 | 13,738,618 |
| 1868 | 8,479,769 |
| 1869 | 7,405,578 |
| | 93,863,065 |

The following tables, chiefly obtained from the Commercial Herald and Market Review, of San Francisco, show the assessments, products, and dividends of leading companies working on the Comstock lode during the last four years. These accounts are based on the operations of each current year. and the figures may therefore appear to differ from some of those already given in foregoing statements, which were based on the operations of each fiscal year of the company concerned:

*Tabular statements of Assessments, Products, and Dividends during the years* 1866, 1867, 1868, *and* 1869, *of the leading claims on the Comstock lode.*

| Claims. | 1866. | | | 1867. | | | 1868. | | | 1869. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Assess-ments. | Products. | Dividends. | Assess-ments. | Products. | Dividends. | Assess-ments. | Products. | Dividends. | Assess-ments. | Products. | Dividends. |
| Alpha | $96,000 | . . . . | . . . | $12,000 | . . . . | . . . | $90,000 | . . . | . . . | $30,000 | | |
| American | . . . | . . . . | . . . | . . . | . . . . | . . . | . . . | . . . | . . . | 34,800 | | |
| Bacon | 18,000 | | | | | | | | | | | |
| Baltimore-American | 13,000 | . . . . | . . . | 5,200 | | | | | | | | |
| Belcher | 143,520 | . . . . | . . . | 74,880 | . . . . | . . . | 104,000 | . . . | . . . | 109,200 | $18,312 | |
| Bullion | 175,000 | . . . . | . . . | 137,500 | . . . . | . . . | 100,000 | . . . | . . . | 67,500 | | |
| California | . . . | . . . . | . . . | 30,600 | | | | | | | | |
| Central | 9,000 | | | | | | | | | | | |
| Chollar-Potosi | . . . | $848,751 00 | . . . | 42,000 | $2,668,885 36 | $420,000 | 140,000 | $885,076 | . . . | . . . | 1,366,385 | $294,000 |
| Confidence | 39,000 | 304,931 71 | . . . | 70,200 | 142,049 46 | . . . | 15,600 | 110,668 | . . . | 31,200 | 18,889 | |
| Consolidated Virginia | . . . | . . . . | . . . | . . . | . . . . | . . . | . . . | . . . | . . . | 52,200 | | |
| Crown Point | . . . | 1,312,471 13 | $234,000 | 60,000 | 920,717 96 | 264,000 | 90,000 | 1,086,230 | $360,000 | 150,000 | 105,718 | |
| Empire Mill and Mining Company. | . . . | 422,291 38 | 32,400 | . . . | 278,607 17 | 49,200 | . . . | 213,771 | . . . | 30,000 | 138,046 | |
| Exchequer | 32,000 | . . . . | . . . | 16,000 | . . . . | . . . | 24,000 | | | | | |
| Gold Hill Quartz | . . . | . . . . | . . . | . . . | 106,399 42 | 33,750 | 10,000 | 103,686 | 7,500 | 10,000 | 65,207 | |
| Gould and Curry | . . . | 1,624,781 01 | 252,000 | 120,000 | 614,620 51 | . . . | 72,000 | 29,557 | . . . | . . . | 350,000 | |
| Hale and Norcross | . . . | 1,186,543 38 | 350,000 | 60,000 | 1,097,297 45 | 440,000 | 200,000 | 392,400 | . . . | . . . | 1,029,812 | 96,000 |
| Imperial | . . . | 910,387 37 | 176,000 | . . . | 1,106,495 50 | 380,000 | 100,000 | 684,040 | 24,000 | 100,000 | 273,727 | |
| Kentuck | . . . | 571,506 79 | 117,000 | . . . | 1,140,741 94 | 505,000 | . . . | 1,259,707 | 480,000 | 40,000 | 828,834 | 80,000 |
| Ophir | 184,800 | 417,472 08 | . . . | 184,800 | 4,108 00 | . . . | 167,000 | . . . | . . . | 134,400 | | |
| Overman | 208,000 | 27,953 00 | . . . | 32,000 | 192,318 17 | . . . | 176,000 | 352,590 | . . . | 128,000 | 336,485 | |
| Savage | . . . | 1,814,879 09 | 320,000 | . . . | 3,737,100 12 | 1,600,000 | . . . | 2,534,868 | 1,184,000 | . . . | 1,162,803 | 280,000 |
| Segregated Belcher | . . . | . . . . | . . . | 6,400 | . . . . | . . . | 38,400 | 4,371 | . . . | 12,800 | | |
| Sides | . . . | . . . . | . . . | 14,000 | | | | | | | | |
| Sierra Nevada | 55,500 | . . . . | . . . | 96,000 | . . . . | . . . | 90,000 | 22,805 | . . . | . . . | 151,360 | 45,000 |
| White and Murphy | . . . | . . . . | . . . | 5,670 | | | | | | | | |
| Yellow Jacket | 180,000 | 2,297,132 94 | 390,000 | 240,000 | 1,729,276 91 | 300,000 | 150,000 | 800,000 | 360,000 | 360,000 | *a* 1,560,000 | 360,000 |
| | 1,153,820 | 11,739,100 88 | 1,871,400 | 1,207,250 | 13,738,617 97 | 3,991,950 | 1,567,000 | 8,479,769 | 2,415,500 | 1,294,600 | 7,405,578 | 1,155,000 |

*a* Estimated.

# CHAPTER IV.

## TREATMENT OF THE COMSTOCK ORES.



### SECTION I.

#### GENERAL OUTLINE OF THE PROCESS.

Classification of ores.—The ores of the Comstock lode consist chiefly of various sulphureted forms of silver, native silver, and gold, finely, almost imperceptibly, disseminated through a gangue of quartz. With these are associated a few other accessory minerals in inconsiderable proportions. Their mineral composition and chemical nature will be more fully discussed in another chapter.

For metallurgical treatment they formerly were, and to some extent still are, divided into three classes. The basis of this assortment is, of course, ar-

bitrary. It is not the same in all mines, and does not appear to have been the same at all times in individual mines. The chief object of the classification is to separate those ores whose mineral composition and, more especially, whose high value demand a very exact and careful treatment in order to obtain the highest possible percentage of their precious contents, from those of lower grade, which must, by reason of their inferior value, be treated by less expensive methods.

The first class usually embraces those ores whose assay value exceeds \$150, or, in some cases, \$100, per ton. The second class, where distinguished at all, is usually designed to include ores whose assay value ranges between \$90 and \$150 per ton. The third class embraces all workable ore of lower grade than the foregoing, the average assay value varying considerably in different mines.

The first-class ores form but a very small proportion of the whole. The tabular statement in the foregoing chapter, showing the ore product, with the actual yield per ton, of some of the principal mines during five years past, although not complete in this respect, will serve to indicate the relative proportions of the several classes of ore. Thus, during the year ending July 1, 1868, the Savage mine produced, including the amount taken out by contractors, 87,341 tons of ore, of which 277½ tons were first-class, having an average assay value of \$449 40 per ton, and an average yield of \$359 52. During the same year 4,745 tons of second-class ore were produced, of which the average assay value was, as determined by two different methods of sampling, \$124 25 and \$142 82 per ton; the average yield being \$78 16. In the following year, in a total product of 69,287 tons of ore, only 68¼ tons were distinguished as first-class, having an average assay value of \$275 47; while no assortment of second-class ore was made in that year. During the year ending July 1, 1868, the average assay value of 78,432½ tons of ore produced by the Savage mine, and denominated as third-class, was, by two different methods of sampling, respectively, \$52 01 and \$55 11 per ton; the average yield being \$37 20. In the following year the average assay value of 55,411 tons of third-class ore reduced was, by the two methods of sampling, \$60 29 and \$50 78 per ton; the average yield being \$34 64.

In many of the mines the proportion of the second-class ore is so small, or the character of the ore so uniform, that no such distinction is made, the whole product being worked without assortment. About twenty-five to thirty per cent. of whole value contained in these ores is gold, the remainder is silver. In the bullion produced the relative proportion of the gold is a little higher, as it is more easily saved than the silver.

The silver of the first-class ores is intimately combined with sulphur, zinc, lead, iron, and other base metals, which render the extraction of the silver difficult. They cannot be profitably treated by the simple methods to which the more docile ores of the second and third classes are subjected, but are crushed dry, roasted with salt in reverberatory furnaces, and then amalgamated in barrels by what is known as the Freiberg process. This will be described with more detail further on. The ores of the second and third classes are treated by one and the same method, known as the pan process; the chief difference, where any exists, in the details of treatment as applied to the two classes, consisting in the duration of time allowed for amalgamation and in the quantity of quicksilver and other chemicals used in the operation.

In the following pages a general description of the method of treatment of these two classes of ores will first be given; the machinery employed for crushing, grinding, and amalgamating will then be described in detail; after which the costs of milling, the yield of the ore and its relation to the assay value, the operations of different mills, the treatment of the "tailings" or residues, and other matters of interest will be discussed.

Crushing.—The ore to be treated by the ordinary Washoe process[1] is delivered from the mine to the mill in pieces varying in size from fine particles to those as large as a man can lift. It needs first to be crushed to a fine condition. This operation is performed by stamps or heavy iron pestles that are lifted and allowed to drop in iron mortars into which the ore is thrown. The larger pieces of ore are first broken to a suitable size for feeding the stamps, either by a sledge or a mechanical rock-breaker, Blake's machine being in general use for this purpose.

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[1] The process of pan amalgamation is commonly known as the "Washoe process," having been first used in the Washoe district.

The stamps vary in weight from 500 to 1,000 pounds; they are lifted and drop about 8 or 9 inches, making from seventy to ninety blows per minute; they are arranged in batteries, which consist, each, of one mortar with usually four or five stamps. Wet crushing is always employed for these ores; that is, a stream of water is admitted to the mortar with the ore, and, flowing off, carries with it the pulverized ore as soon as the latter is sufficiently reduced in size to pass through the screens placed in front of the discharging apertures of the mortar.

The screens through which the crushed material is discharged from the mortar are either of brass wire-cloth, having 35 or 40 meshes to the lineal inch, or more frequently of Russia sheet-iron, perforated with fine holes. Screens of the latter sort, in general use, are known as Nos. 5 or 6. In the last named the hole has a diameter of $\frac{1}{40}$ of an inch.

In former years the amalgamation of the precious metals of the ore with quicksilver was carried on in the mortar, a supply of quicksilver for that purpose being introduced with the rock into the mortar. This feature of the process has, however, now been given up in the mills of the Washoe district. The stuff being discharged from the battery is conveyed in troughs by means of the flowing water to settling tanks, of which there is a series placed in front of the batteries. These tanks are usually built of plank, are 3 or 4 feet deep by 5 or 6 or more feet square, and are so arranged as to have communication with each other near the top, so that the stream of water carrying the crushed ore in suspension, having filled one tank may pass into the next, and so on through several, depositing the material and not finally leaving the tanks until it has become tolerably clear. The number of tanks must be sufficient to allow of a certain portion being emptied while others are receiving their supply, and the conveying troughs are provided with gates so arranged that the stream can be admitted to one portion of the tanks and shut off from the other at pleasure. The stream, having deposited in these tanks the bulk of the material, is still charged with slimes, or rock reduced to an impalpably fine condition, which is only settled by a slow process. For this purpose the stream is sometimes permitted to pass through other large settling tanks, or to slowly deposit its charge in a pond or dam outside the mill, where such an arrange-

ment is possible. These slimes form a variable and in some mills a large percentage of the whole amount crushed; in some instances, it is stated, more than ten per cent.; and although they have a high assay value they have not until recently been worked successfully and with profit. When one or more of the settling tanks in the mill have been filled the stream is diverted from such to others that have been emptied, and the full ones are in their turn cleaned out, the sand or crushed ore being then subjected to the grinding and amalgamating process of the pan.

Grinding and Amalgamation.—Pans.—The pans employed for this purpose present a great variety in the details of construction. Since the first "common pan," a very simple form of apparatus, came into use, many inventors have exercised their ingenuity in devising improvements, and at present there are several different patterns, each of which has some special claim for excellence, and finds its advocates among the practical mill-men of the district. A more detailed description of some of these will be found further on. The common features are a round tub, see Plates XXI and XXII, usually of cast-iron, but sometimes with wooden sides, 4 to 6 feet in diameter and about 2 feet deep, having a hollow pillar cast in the center, within which is an upright shaft projecting above the top of the pillar that may be set in revolution by gearing below the pan. To the top of this shaft is attached, by means of a key or feather, a yoke or driver by which the muller or upper grinding surface is set in motion. To the bottom of the pan, on the inside, is fixed a false bottom of iron, cast either in sections, commonly called dies, or in one piece, having a diameter a little less than that of the pan, and with a hole in the center adapted to the central pillar. This serves as the lower grinding surface. The muller, forming the upper grinding surface, is usually a circular plate of iron corresponding in size and form to the false bottom just described, having a diameter nearly equal to that of the pan, and a flat, conical, or conoidal form, according to the shape of the pan-bottom. Its under side is furnished with shoes or facings of iron, about an inch thick, that may be removed when worn down and replaced by new. The muller is attached to the driver, which is put on and over the central pillar of the pan and, being connected with the interior upright shaft as above described, is thus caused to

revolve. There are various appliances for raising or lowering the muller, so that it may rest with its whole weight upon the pan-bottom in order to produce the greatest grinding effect, or be maintained at any desired distance above it when less friction or mere agitation is required. Various devices are also in use for giving proper motion to the pulp, so that, when the muller is in revolution, the material may be kept constantly in circulation, passing between the grinding surfaces and coming into contact with the quicksilver. Some pans are cast with a hollow chamber, an inch or two deep in the bottom, for the admission of steam in order to heat the pulp, while others employ only "live steam," which is delivered directly into the pulp by a pipe for that purpose.

The operation of the pan consists in the further reduction or grinding of the stamped rock to a fine pulp and in the extraction of the precious metals by amalgamation with quicksilver. The quantity of ore with which a pan is charged for a single operation varies from 600 or 800 to 4,000 or 5,000 pounds, according to the size of the pan. The ordinary charge of pans, most generally in use at present, is 1,200 to 1,500 pounds.

In charging the pan the muller is raised a little from the bottom, so as to revolve freely at first, water is supplied by a hose pipe, and at the same time the sand is thrown into the pan with a shovel. Steam is admitted, either to the steam-chamber in the bottom of the pan or directly into the pulp. In the former case the temperature can hardly be raised as high as in the latter; but, on the other hand, when steam is introduced directly, care is necessary to avoid reducing too much the consistency of the pulp by the water of condensation. The pulp should be sufficiently liquid to be kept in free circulation, but thick enough to carry in suspension, throughout its entire mass, the finely divided globules of quicksilver. In some mills both methods of heating are employed in the same pans, the temperature being first raised with each charge by live steam, and afterward sustained by admitting steam to the chamber only. Some pans are covered with wooden covers to assist in retaining the heat. When properly managed the temperature may be kept at or near 200° Fahrenheit. When, in the use of live steam, the pulp becomes too thin the supply of steam is cut off, the covers removed, and the pulp allowed to thicken by the evaporation of the water. The steam in the chamber may keep the temperature up to the desired point in the meantime. Another advantage of

the steam-chamber is that the exhaust-steam from the engine may be used in it, while for use in the pulp it is better and customary to take steam directly from the boilers, because that which comes from the cylinder of the engine is charged with oil and is injurious to amalgamation. The muller is gradually lowered after the commencement of the grinding operation, and is allowed to make about 60 or 70 revolutions per minute. In the course of an hour or two the sand should be reduced to a fine pulpy condition. When this has been accomplished, and by some mill-men at a still earlier stage (even at the beginning) of the operation, a supply of quicksilver is introduced into the pan, the muller slightly raised from the bottom to avoid too great friction, which would act to the disadvantage of the quicksilver, and the action continued for two hours longer, during which the amalgamation is in progress. The quicksilver is supplied by pressing it through canvass, so as to scatter it upon the pulp in a finely divided condition. The quantity varies greatly in different mills, the ordinary supply being about 60 or 70 pounds to a charge of ore consisting of 1,200 or 1,500 pounds. In some mills a quantity, varying from 75 to 200 or even 300 pounds, is put into a pan when starting up after a clean-up, and subsequently a regular addition of 50 or 60 pounds made with each charge.

To promote amalgamation it is the general custom to add to the charge, either at or soon after the beginning of the grinding, or at the time of supplying the quicksilver, various materials generally described as "chemicals," and usually consisting, at the present day, of sulphate of copper and salt. Since the first introduction of the pan process a great variety of substances supposed to effect the decomposition of the silver sulphurets and to facilitate amalgamation have been suggested by process-vendors, and employed by men possessing little or no knowledge of the science of chemistry. Even tobacco-juice, decoction of sage-bush, and various other equally absurd ingredients are said to have been used by some operators and believed to be effective reagents in the decomposition of the ore and amalgamation of the silver. The long list of materials once in use has now been reduced, excepting in few places, to sulphate of copper and salt. The quantity used varies from a quarter or half a pound to three or four pounds to each charge of ore; the two substances being employed in very variable proportions in different mills. The action of these, however,

which is generally supposed to be analogous to that produced by the same reagents in the Mexican "patio" process, is but imperfectly understood, and their efficiency, *at least in the manner and proportions in which they are at present employed,* may well be doubted. This is apparent from the fact that in some mills both sulphate of copper and salt are used, in others only the first is used without the second, and in others only the second without the first, or, if at all, in proportions so minute that its efficient action is incredible; others have dispensed with the use of "chemicals" altogether, and under all these varying circumstances equally good results have been obtained. Some mills, accustomed to use both salt and sulphate of copper, have dropped either one or the other, while working continuously on the same kind of ore, without perceiving any difference in the result; and it is the opinion of many intelligent mill-men that neither salt nor sulphate of copper, in the manner and quantity as at present employed, are essential to the efficient working of the ore in pans. This subject will be further discussed on a following page.

Two hours having been devoted to the grinding, and two or three more to amalgamation, the pan is discharged and its contents received by a settler or separator. The discharge of the pan is usually aided by a supply of water, which dilutes the pulp and permits it to run freely from the pan into the settler. The pan being emptied and partly washed out by the stream of water, is again charged with a fresh quantity of sand and the grinding operation is resumed without delay.

Settlers or Separators.—These, like the pans, differ somewhat in details of construction, but they usually are round tubs of iron or of wood with cast-iron bottoms, resembling the pans in general features, but larger in diameter. A hollow pillar or cone, *C*, Figs. 1 and 2, Plate XVII, is cast in the center of the bottom, within which is an upright shaft, *S*. This shaft is caused to revolve by gearing below the pan. To its upper end is attached a yoke or driver, *D*, that gives revolving motion to arms, A, extending from the center to the circumference of the vessel. The arms carry a number of plows, or stirrers, of various devices, usually terminating in blocks of hard wood, *P*, that rest lightly on the bottom. No grinding is required in the operation, but a gentle stirring or agitation of the pulp is desired in order to facilitate the settling of the amalgam and the quicksilver. The stirring apparatus, or muller, makes about fifteen revolutions per minute.

# SEPARATOR or SETTLER.

Scale: $\frac{1}{24}$

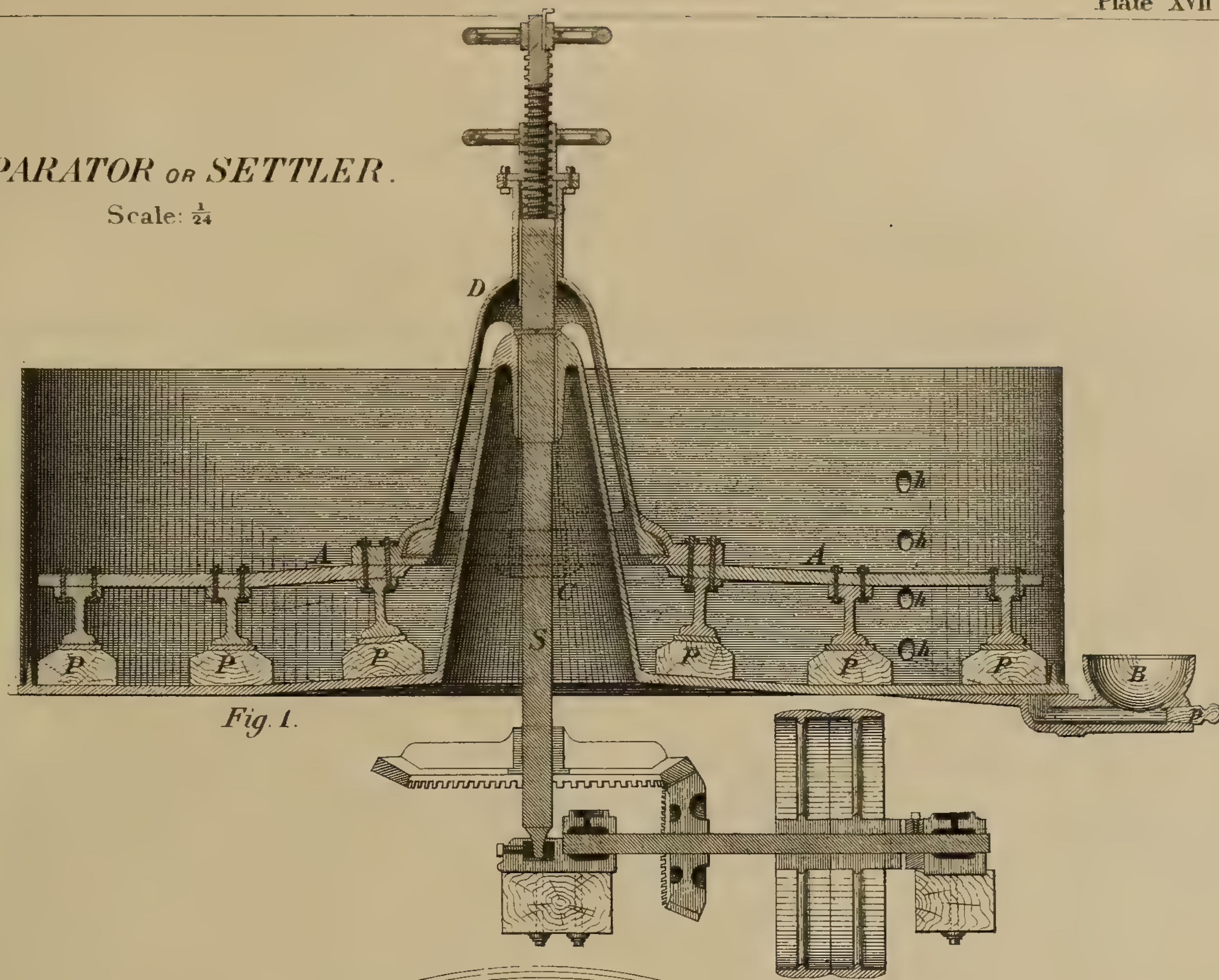
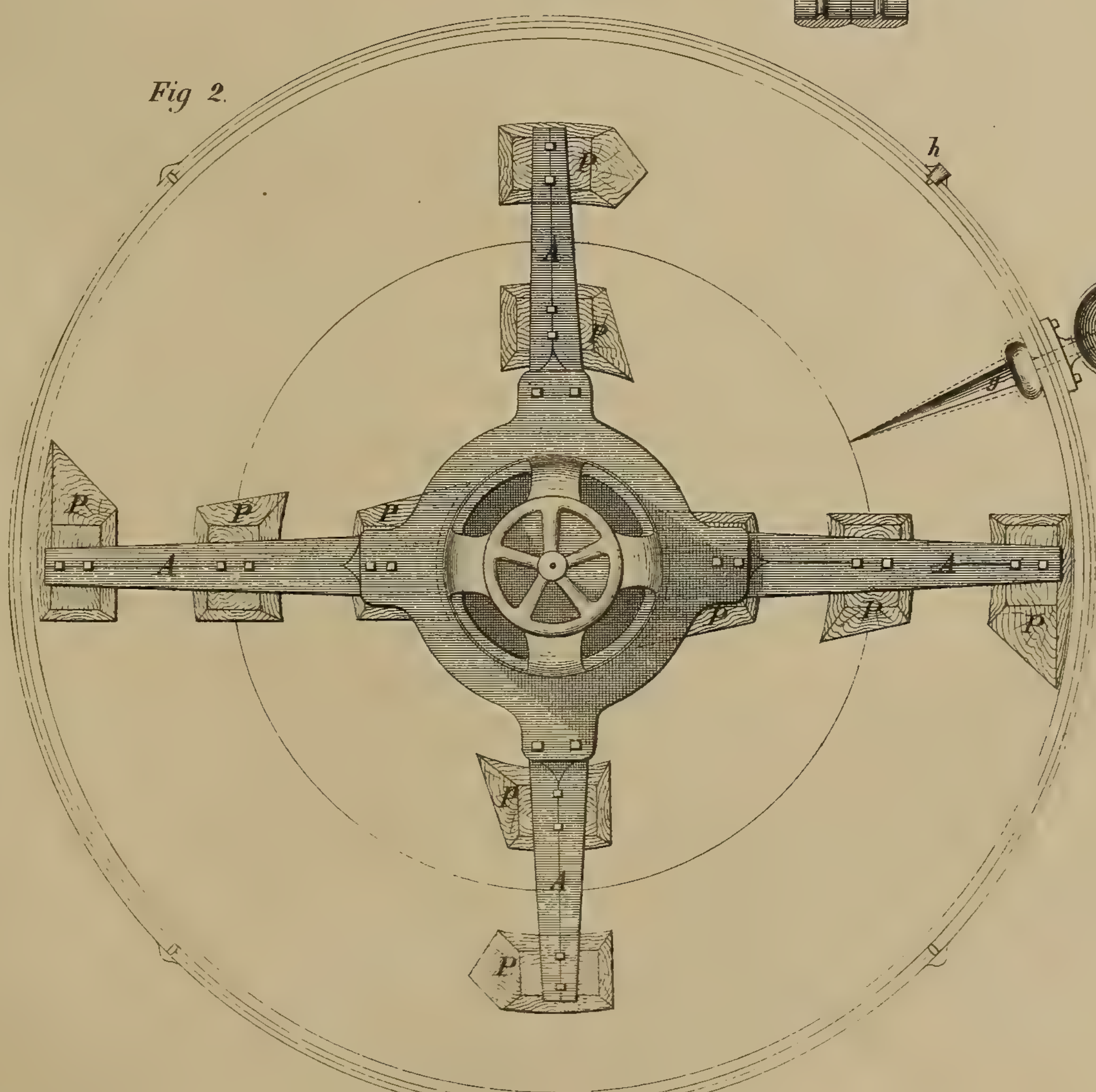



Fig. 1.

Fig 2.



The settler is usually placed directly in front of the pan and on a lower level, so that the pan is readily discharged into it. In some mills two pans are discharged into one settler, the operation of settling occupying four hours, or the time required by the pan to grind and amalgamate another charge. In other mills the settling is allowed only two hours, and the two pans connected with any one settler are discharged alternately.

The consistency of the pulp in the settler is considerably diluted by the water used in discharging the pan and by a further supply, which in many mills is kept up during the settling operation. In other mills, however, the pulp is brought from the pan into the settler with the addition of as little water as possible, and allowed to settle for a time by the gentle agitation of the slowly revolving muller, after which cold water is added in a constant stream. The quantity of water used, affecting the consistency of the pulp, and the speed of the stirring apparatus are important matters in the operation of settling or separating. Since the object of the process is to allow the quicksilver and amalgam to separate themselves from the pulp and settle to the bottom of the vessel, it is desirable that the consistency should be such that the lighter particles may be kept in suspension by a gentle movement, while the heavier particles fall to the bottom. If the pulp be too thick the metal will remain suspended; if it be too thin the sand will settle with it. Too rapid or too slow motion may produce results similar to the above-named, because by too violent motion the quicksilver will not be allowed to come to rest on the bottom, while if the motion be too slow the coarser sand will not be kept in circulation.

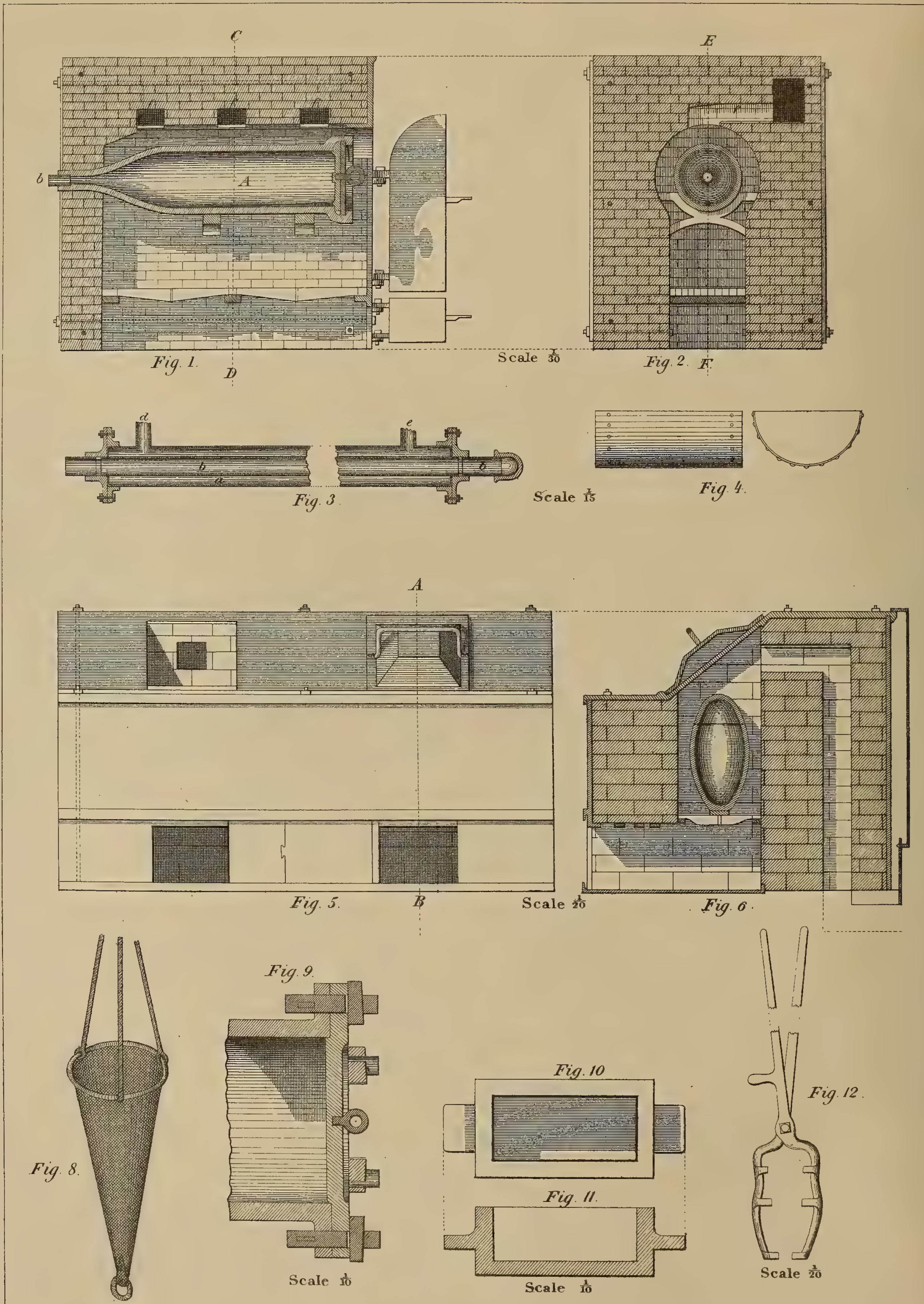
A discharge hole, near the top of the settler, permits the water carrying the lighter portion of the pulp to run off, and at successive intervals the point of discharge is lowered by withdrawing the plugs from a series of similar holes, *h*, *h*, in the side of the settler, one below the other, so that finally the entire mass is drawn off, leaving nothing in the settler but the quicksilver and amalgam. There are various devices for discharging these. Usually, there is a groove or canal in the bottom of the vessel, as shown in Figs. 1 and 2, Plate XVII, leading to a bowl, *B*, from which the fluid amalgam may be dipped or allowed to run out by withdrawing the plug, *p*, from the outlet-pipe.

The quicksilver charged with amalgam is carefully cleaned by washing with water and removing from the surface the associated impurities such as heavy particles of dirt, pyrites, &c. In some cases the cleaning is performed in a small iron pan, resembling the settler in manner of construction but much smaller, in which it is stirred slowly with plenty of clean water, which serves to wash out the impurities and remove them from the pan. When properly cleaned the amalgam is strained through a canvas filter or conical bag, 10 or 12 inches in diameter at the top, and 2 or 3 feet long. (See Fig. 8, Plate XVIII.) The quicksilver is drained off and returned to the pans for further use, while the amalgam is thus obtained for the retort.

In some mills this straining is not performed after every charge of ore, as is the case in others, but only at stated times, say once in twenty-four hours, or once in three or four days. Under such circumstances a considerable quantity of quicksilver is kept in the settler, sometimes 200 or 300 pounds. This excess of quicksilver, holding the amalgam in solution, is in a highly fluid condition, and when discharged from the settler by means of the tube and cistern just described, it is returned to the pan for further amalgamation, its "charged" condition—that is, having silver already in combination—being considered an advantage, as it is thought to be more active than pure metal in the amalgamating process. In some mills, at a stated hour of each day, the quicksilver coming from the settlers is strained and the amalgam extracted; in others, as the quicksilver thickens or becomes sluggish by the accumulation of amalgam, it is diluted by the addition of fresh quicksilver, and the straining of the amalgam is only made once in several days

From time to time, as at the end of the month or other given period, or when any special lot of ore has been finished, of which it is desired to know the exact yield, the pans and settlers must be stopped and cleaned up thoroughly. For this purpose the mullers must be raised, the shoes and dies removed from their places, and all the iron work of the pans and settlers carefully scraped with a knife to remove and collect the hard amalgam which attaches itself to such surfaces. In many cases one-fourth or even a greater proportion of the total product of amalgam is obtained in this way.

Retorting and Melting.—The amalgam, having been strained in the bags and forcibly pressed, in order to expel as much of the fluid quick-


C
b
A
Fig. 1.
D
E
Fig. 2.
F
Scale 1/30
d
e
b
a
b
Fig. 3.
Scale 1/15
Fig. 4.
A
Fig. 5.
B
Scale 1/20
Fig. 6.
Fig. 8.
Fig. 9.
Scale 1/10
Fig. 10.
Fig. 11.
Scale 1/10
Fig. 12.
Scale 1/20

silver as possible, is then subjected to the process of sublimation, by which means the quicksilver is separated from the gold and silver. This is effected in a cast-iron retort. The retorts in use are of various forms, but the most-approved is cylindrical, about 12 inches in diameter inside, and from 3 to 5 feet long; the casting being an inch and a half thick. (See Figs. 1 and 2, Plate XVIII.) The open end of the retort, or the end by which the charge is introduced, is cast with a flange or hood into which the door or cover of the retort is fitted. Within the cylindric portion of this flange or hood are two inclined lugs, opposite each other. A bar or bale, turning upon a pin in the center of the door, holds it firmly in its place by the ends of the bar being turned under the inclined lugs. When charged, the joint between the door and the bottom of the flange is made tight by means of clay luting. Another method of securing the door is shown in Fig. 9, Plate XVIII. The opposite end of the retort is usually made conoidal in form. In such case the main cylindrical portion, 12 inches in diameter, is 3 feet long, at which point the diameter of the conoidal neck is gradually diminished to 2½ inches at the extreme end of the retort, from which the exhaust pipe, *b*, the purpose of which is to afford escape to the volatilized quicksilver, turns downward and passes through the condenser, the construction of which is shown in Fig. 3. This is usually arranged on the principle of the Liebig condenser and consists of a pipe, *a*, of considerably larger diameter than the exhaust pipe, *b*, so that the latter may pass entirely through the former, which, when in use, is kept constantly supplied with cold water by a pipe, *d*, opening into the bottom, the heated water flowing off at the outlet, *e*, near the top. The quicksilver condensing in the exhaust-pipe falls into a receiver, placed under the end of the pipe, and which is also nearly full of water. The end of the exhaust pipe dips below the surface of the water to prevent access of air but not sufficiently to permit the passage of the water into the heated retort under any circumstances.

The retort is set in a brick furnace of simple construction, sometimes supported by a brick arch, through which a number of flues permit the passage of the heat from the fire-place below, sometimes resting on cross-bars of iron, the ends of which are fixed in the brick sides of the furnace, as shown in Fig. 1, Plate XVIII. Directly below the retort, extending under its whole

length, is the fire-place and ash-pit. Above it is an arch, from the top of which the flues, *f*, lead to the stack. Some retorts are set in such manner that temporary brick-work may be built up in front of the door during the sublimation to prevent the escape of heat. Dampers are so arranged that the heat may be applied more or less vigorously to the front, back, or middle of the retort according to its requirements.

The retort is furnished with amalgam trays, illustrated by Fig. 4, Plate XVIII, having a semi-circular shape adapted to the bottom of the cylinder. There are usually several of these, and they are of a size convenient for handling when loaded with amalgam. In many mills, however, they are not used, the amalgam being charged directly upon the bottom of the retort. Before introducing the amalgam into the tray or the retort the surface of the latter is covered with a thin wash of clay or slime, such as is produced in stamping, to prevent the metal from adhering to the iron. Whiting, wood ashes, or paper are sometimes used for this purpose and recommended as being less likely to choke the pores of the bullion. The amalgam being placed in the retort and the door properly adjusted and luted with clay, the fire is lighted and heat is applied, at first very gently and afterward gradually increased. If heated too strongly at first the surface of the bullion in contact with the retort is liable to fuse and prevent the escape of quicksilver from the central part. The charge for a cylinder of the dimensions above described is about 1,200 pounds. The firing usually occupies about eight hours. When quicksilver ceases to volatilize, the retort is gradually cooled down and the bullion withdrawn. About one-sixth of the original charge usually remains, or 200 pounds of crude bullion from 1,200 pounds of amalgam. This retorted amalgam is broken up, melted, and cast in ingots ready for market. The melting furnace commonly used for this purpose is shown in Figs. 5 and 6 on Plate XVIII. Fig. 5 is a front elevation of a double furnace. The cover of the left-hand furnace is removed, showing the size and position of the flue. Fig. 6 is a transverse section on the line *A B* in Fig. 5. Fig. 12 shows the tongs for removing the melting pot. Fig. 10 shows the form of ingot mold usually employed. The loss of weight in melting the retorted amalgam, or crude bullion, is between two and three per cent. The ingots, when obtained, are assayed, and their fineness, expressing the proportions of gold and silver contained in thousandths, as well as

their coin value, in dollars and cents, are stamped upon them. The value of the ounce of bullion ready for market usually varies between $1 75 and $2; the gold representing about one-third and the silver about two-thirds of the whole amount.

The pulp, after passing from the settlers, in which, as before described, the quicksilver and amalgam are separated from it, is variously treated in different mills. Frequently the whole mass is allowed to pass through agitators, tubs or vats of various devices, for the purpose of saving some of the quicksilver and amalgam that is unavoidably carried off with it from the settler. In some mills various kinds of concentrators are employed for a similar purpose, and to obtain the heavy undecomposed sulphurets in concentrated form; in other cases, where there is water sufficient and the lay of the land favorable, blanket-tables are constructed outside the mill, over which the stream of tailings[1] is allowed to run, and a portion of their valuable contents caught in blankets; and, at convenient points, dams are constructed for the accumulation of tailings, which, after months of exposure to the influences of the weather, may be again worked over with profit.

The ordinary working result obtained by treating the ore as above described in the pan and settler varies between sixty-five and seventy-five per cent. of the assay value, which, by subsequent treatment, as just indicated in the foregoing paragraph, is increased sometimes to eighty-five or ninety per cent., or possibly a little more. This subject, as well as the costs of working and many other interesting details connected with the business, will be considered more minutely further on, after having first described, in detail, some of the various kinds of crushing and grinding machinery employed in the process, of which the main features have just been given.

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[1] The term "tailings" is applied to the residue of sand or pulp that leaves the separator or agitator after the principal portion of its valuable contents has been extracted. The term "slimes" generally applies to that portion of the ore which is crushed under the stamps to an impalpably fine condition, and which usually passes out of the mill without being deposited in the tanks, where the coarser sands are collected for pan treatment. The difference in the value, mechanical condition, and methods of treatment of "tailings" and "slimes" makes the distinction between them an important one. That part of the "tailings" which, by grinding in the pan, has been reduced to a slimy condition, is sometimes called "pan slimes," and thus distinguished from "battery slimes."

## SECTION II.

### DETAILS OF MACHINERY EMPLOYED IN CRUSHING AND AMALGAMATING.[1]

The machinery of a mill for the treatment of silver ores by the "wet process," or method just indicated, consists of rock-breakers and stamps for crushing; pans, for grinding and amalgamation; settlers, for the separation of the quicksilver and amalgam from the pulp; agitators, which are supplementary to the settlers, and save escaping quicksilver; various appliances for the concentration of the residue, or "tailings;" the retort for the sublimation and separation of the quicksilver from the precious metals; besides the motive power and its auxiliary parts.

The rock-breaker generally in use is Blake's. It serves simply to crush the large pieces of rock to fragments of smaller size, not exceeding a few cubic inches, which are then conveniently supplied to the stamps. The machine is well known, not only in mining regions but throughout the country, being employed in breaking stone for road-making and other purposes. It hardly needs a detailed description here.

Stamps.—The stamps consist of a series of heavy pestles of iron, which are lifted to a height varying from 7 to 15 inches, and allowed to fall upon the ore that is to be crushed. They work in a mortar or trough, also of iron, into which a constant supply of ore is introduced, and from which the crushed material escapes through openings furnished with closely fitting screens, as soon as it is reduced to the desired degree of fineness. The mortar is usually rectangular in form, and contains from three to six, commonly five, stamps, forming what, in this country, is called a "battery." The mortars rest on a solid foundation, and are established in a substantial framework of timber. The stamps are lifted by means of revolving cams or arms of iron, keyed to a cam-

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[1] Although the writer has prepared this section almost entirely from his own notes or personal observation, he has made frequent reference to several well-known works, chief among which is Küstel's Concentration and Chlorination, an excellent treatise on the mechanical preparation of ores. Professor Gaetzschmann's valuable work, "Die Aufbereitung," and Rittinger's "Lehrbuch der Aufbereitungs-Kunde," are commended to the student as complete and thoroughly scientific discussions of the same subject.

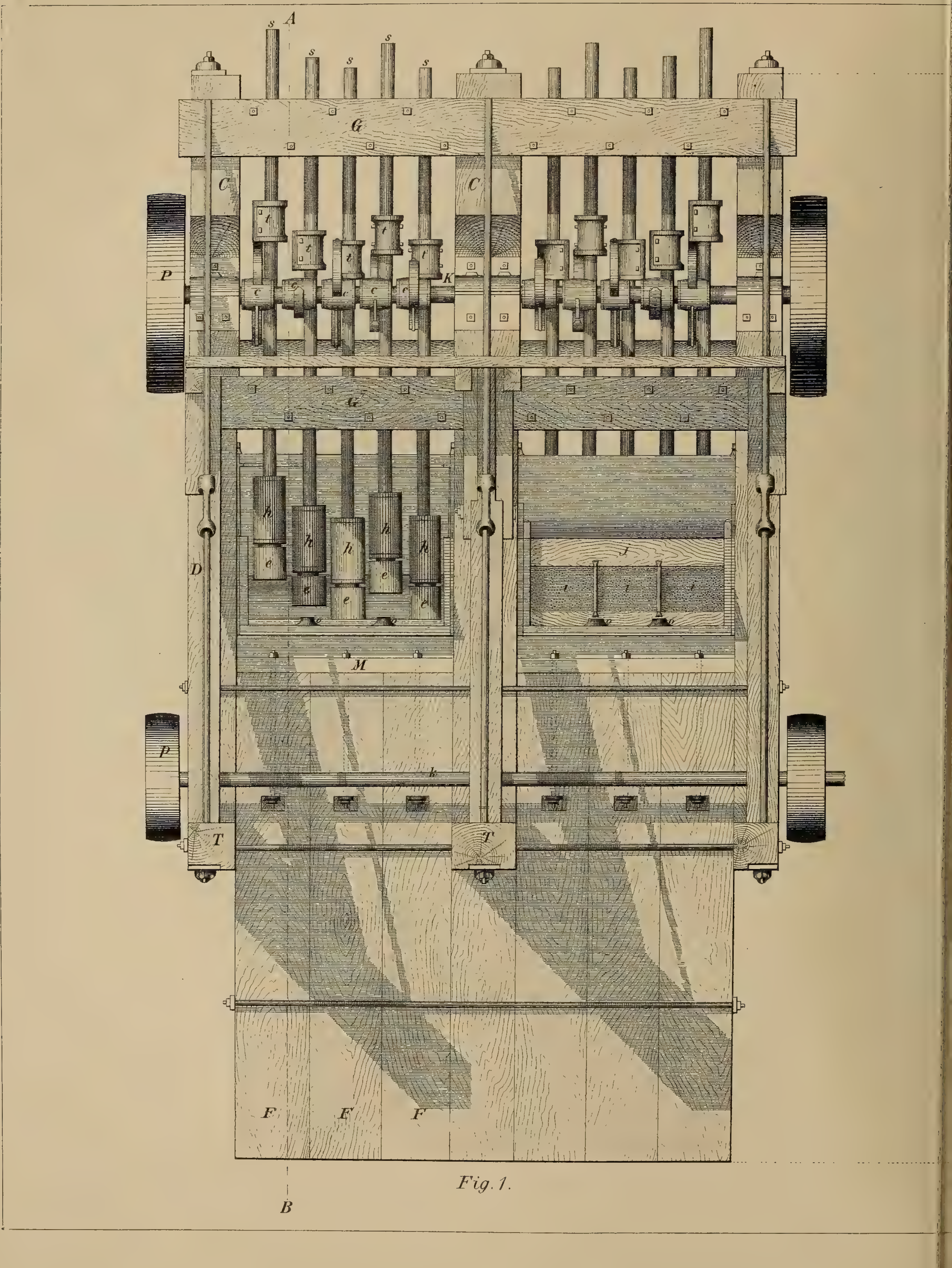
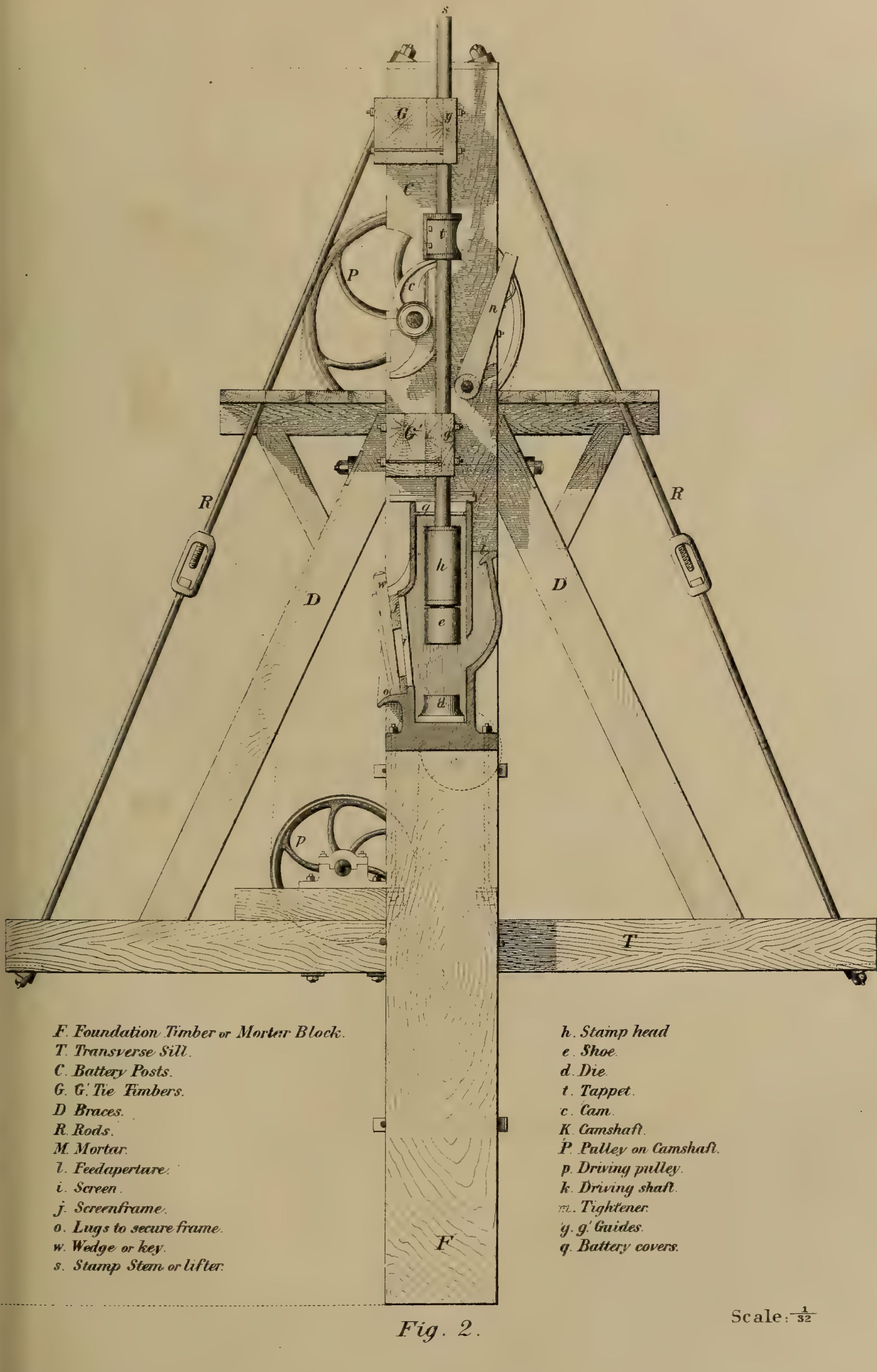



Fig. 1.




*F.* *Foundation Timber or Mortar Block.*
*T.* *Transverse Sill.*
*C.* *Battery Posts.*
*G. G'.* *Tie Timbers.*
*D.* *Braces.*
*R.* *Rods.*
*M.* *Mortar.*
*l.* *Feedaperture.*
*i.* *Screen.*
*j.* *Screenframe.*
*o.* *Lugs to secure frame.*
*w.* *Wedge or key.*
*s.* *Stamp Stem or lifter.*

*h.* *Stamp head*
*e.* *Shoe.*
*d.* *Die.*
*t.* *Tappet.*
*c.* *Cam.*
*K.* *Camshaft.*
*P.* *Pulley on Camshaft.*
*p.* *Driving pulley.*
*k.* *Driving shaft.*
*n.* *Tightener.*
*g. g'.* *Guides.*
*q.* *Battery covers.*

*Fig. 2.*

Scale: $\frac{1}{32}$

shaft, which is placed directly in front of the batteries, and which receives its motion from the driving power of the mill. The stamps move vertically between guides that form a part of the battery frame.

Fig. 1, on Plate XIX, shows a front elevation, and Fig. 2, a transverse section, on the line *A B* of Fig. 1, of two five-stamp batteries, the several parts of which are indicated by the table of reference accompanying the drawing.

The foundation for the batteries in stamp mills generally preferred in Nevada, as well as in California, consists usually of heavy timbers, standing vertically, placed close together, and firmly connected by means of cross timbers and bolts of iron. The timbers are from 6 to 12 feet long, according to the character of the ground and the desired height of discharge for the mortar. Sometimes they stand on a horizontal timber, so laid as to serve as the base of two or more batteries, and resting upon the ground, the surface of which has previously been removed and leveled down sufficiently for the whole number of batteries to be placed on a firm bottom. When the foundation-timbers are in place, the space about them is packed and stamped as firmly as possible with clay or earth. Where the ground on which the batteries are to be built is a hard, compact gravel or a firm, clayey material, the surface is sometimes leveled off so as to admit of laying the transverse sill-timbers, *T*, of the battery frame, and a narrow pit is then excavated, only long and wide enough to receive the ends of the mortar-blocks, and several feet deep, into which the posts or blocks are introduced, in a vertical position, their bottom ends resting directly on the ground, without any intervening horizontal timber. The remaining space in the pit may then be compactly filled with clay that is pounded or stamped firmly into its place. The sill-timbers, *T*, and the battery posts, *C*, are securely bolted to the foundation-timbers. The posts, *C*, are braced by the timbers, *D*, and the rods, *R*, and are connected by the tie timbers, *G*, *G'*, which also support the guides, *g*, *g'*.

MORTARS.—The mortars are now usually placed directly upon the vertical mortar-blocks, without any horizontal piece intervening, and are secured in their place by bolts shown in the figure. They may be constructed of wood and iron, having a solid iron bed-plate, with sides and ends of wood, forming the stamping trough; or they may be made entirely of iron. In the

former case there is often great difficulty in keeping the mortar tight enough to prevent leakage and consequent waste of ore.

The mortar in general use for wet-crushing is an iron box or trough about 4 or 5 feet in length and depth, and 12 inches, inside, in width, and so cast that bottom, sides, and ends are in one piece. A front and end view of one of the most-approved forms is shown in place, in the drawing of a battery of stamps, on Plate XIX. The feed opening, *l*, is an aperture about 3 or 4 inches wide and nearly as long as the mortar, by means of which the rock is supplied to the stamps. On the opposite side is the discharge opening, furnished with a screen, *i*, through which the crushed material must pass. This opening is as long as the mortar, or nearly so, and 12 to 18 inches deep, the lower edge being 2 or 3 inches above the top of the die. In some mortars, especially for dry crushing, the discharge is on both sides, in which case the feed-opening is above the screen; but the single discharge is in general use in the Washoe district.

The screen is attached to a screen frame, *j*, which is secured in grooves cast in each end of the mortar, and by two lugs, *o*, cast in front of the discharge-opening, being held firmly in place by a wedge driven behind it in the grooves just referred to.

Screens are sometimes placed vertically, sometimes inclined, as shown in the figure. The discharge is generally thought to be better in the latter case. Screens are made of fine brass wire-cloth, having from 40 to 60 meshes to the lineal inch, or, more generally for wet-crushing, of Russia sheet-iron, perforated by finely punched holes, varying from $\frac{1}{40}$ to $\frac{1}{24}$ of an inch in diameter. The wire-cloth or sheet-iron plate is attached to the screen-frame by nails or screws. The punched plate is preferred for wet crushing. The wire-cloth, though affording more discharging surface, wears out faster, and not only is more liable to break, and so permit large particles to pass through, but frequently stretches, giving meshes of irregular size. A piece of canvas is usually hung before the screen for the crushed ore to splash against as it issues from the mortar, falling thence into the trough below.

Dies.—The mortar is furnished with dies which are so fixed in the bottom as to receive the blow of the stamp and sustain the wear which would, in its absence, fall upon the mortar itself. The die is a cylindrical piece of

cast iron, corresponding in form to the shoe of the stamp that falls upon it. It is from 4 to 6 inches high. In the bottom of some mortars there are circular recesses made for the reception of the dies which are caused to fit into them. In others, to prevent the rock from working in under the die and displacing it, the circular recess in the bed-plate is cast with a flange, and the die with a small projection or lug. A groove is also made in the bottom of the mortar, so that the die may be introduced with its lugs dropping into the groove. The die being then turned about 90 degrees, the lugs come under the flanges of the recess and the die consequently held in place. A simpler and the most common form is to cast the cylindrical part of the die on a flat, square base, as shown in Fig. 1, Plate XX. The bottom of the mortar is also made flat and the dies dropped in, resting on their bases, which just fill up the space in the bottom of the mortar. The corners of the bases of the dies are beveled off so as to allow the insertion of the point of a pick, by which means they can be taken out when necessary.

In addition to the dies, plates of iron, a half-inch thick, are sometimes applied to the sides and ends of the mortar, exposed to constant wear, which, like the dies, can be taken out and renewed when necessary. The top of the mortar is covered by two pieces of plank, cut so as to fit closely, and resting on flanges cast on each end. Semi-circular recesses, cut opposite each other on the adjacent edges of the two pieces of plank, afford a passage for the movement of the stamp-stems.

The stamp consists of a stem or lifter; a head or socket, attached to the lower end of the stem, and furnished with the shoe, a movable part which sustains the force of the blows and the wear of the operation; and the collar, or tappet, by means of which the revolving cam lifts the stamp for its fall. The stem is a round bar of wrought iron, about three inches in diameter, usually turned in a lathe. Its length is 10 or 12 feet. Its lower end is slightly tapered and corresponds in form to a socket or conical hole in the upper part of the stamp-head. The rest of the stem is usually made round throughout its entire length, the method, now in general use, of attaching the tappets to the stems not requiring any modification in the form of the latter, as was formerly the case.

The stamp-head, illustrated by Fig. 2, Plate XX, is a cylindrical piece

of tough cast iron about 8 inches in diameter and 15 inches high. In its upper end is a socket, shown by dotted lines, corresponding with the axis of the cylinder and conical in form, designed to receive the slightly tapering end of the stem, to the dimensions of which it must be adapted. This conical hole, or socket, is about 7 inches deep. At its bottom is a hole, or key-way, *a*, passing through the head, at right angles to the cylindrical axis, by which passage a key may be driven in to force the head from the stem when necessary.

To attach the stamp-head to the stem, the latter is placed in its position between its guides, and the head standing immediately under it. The stem being dropped enters the socket, and a few blows of the hammer drive it in with sufficient force to cause the head to be raised when the stem is lifted. The stem and head, being suffered to drop together a few times, become firmly connected. In the lower end of the head is a similar hole or socket, *b*, but larger than the upper one, likewise tapering or conical in form, made to receive the stem or shank of the shoe, which is thus connected with the head in similar manner; a rectangular hole, or passage, *c*, through the head at the end of this lower socket permits the removal of the shoe in the same way as the stamp-stem is forced out from the upper socket. A stout wrought-iron hoop encircles each end of the stamp-head, being fitted and driven on when hot and allowed to shrink in place.

The shoe in common use in these mills is a cylindrical piece of cast iron about 8 inches in diameter and 6 inches high, above which is a shank or stem, the base of which is 4 or 5 inches in diameter, tapering in form and about 5 inches high. It is made of the hardest white iron. It is attached to the head in manner somewhat similar to that just described for connecting the head and the stem, but is wedged on by means of strips of pine wood. These strips which are cut about as long as the stem of the shoe, a quarter of an inch thick and about a half an inch wide, are placed around the stem of the shoe and tied with a piece of twine, as shown in Fig. 3, Plate XX. They must be thick enough to wedge the stem of the shoe firmly in its socket, without allowing the head to come in contact with the body of the shoe. When the shoe is ready to be fixed to the head it is placed in proper position with the stem of the shoe directly under the socket of the head, and the

stamp and head are then allowed to drop upon it. If necessary, a few blows of the hammer must be struck upon the top of the stamp-stem. The whole may then be raised, the shoe keeping its place, and suffered to fall repeatedly until the shoe is firmly established in the socket. During this operation a piece of plank is interposed between the die on the bottom of the mortar and the shoe for the latter to strike upon. Whenever a shoe has been worn out it may be removed from the socket by driving the key into the key-way, *c*, and forcing it off. Care is required that the shoe does not become so thin as to permit the head to sustain undue wear and so become weakened. Shoes should be removed when worn down to one inch of thickness.

The collar, or tappet, is a projecting piece, firmly secured to the upper part of the stem, by means of which the revolving cam may lift the stamp and let it fall upon the substance to be crushed. Tappets vary in form and method of attachment to the stem, but that which seems to combine the greatest number of advantages and to have been most generally adopted in California and Nevada is that which is known as Wheeler's gib-tappet. Fig. 4, on Plate XX, shows an elevation and vertical section of this contrivance. It is a piece of cast iron, cylindrical in form, about 8 inches in height and diameter, hollow at the center so as to receive the stamp-stem. To secure the tappet to the stem there is a gib, *g*, about 2 inches wide and nearly as long as the tappet, having its inside face curved so as to correspond in form to the circular hole through which the stem passes. The gib being fixed in its place in the tappet and the latter being put upon the stem, it is pressed against the stem by means of two keys, *k*, *k*, driven into the key-ways, with force sufficient to hold the tappet and stem firmly together and prevent slipping between them. This is found to be a very effective method of securing the tappet while permitting it to be fixed at any desired point on the stem, according to the wear of the shoe. The stem is uniform in size and the work of cutting facings, screw-threads, and key-seats on the stem, required by other methods in use elsewhere, is thus avoided.

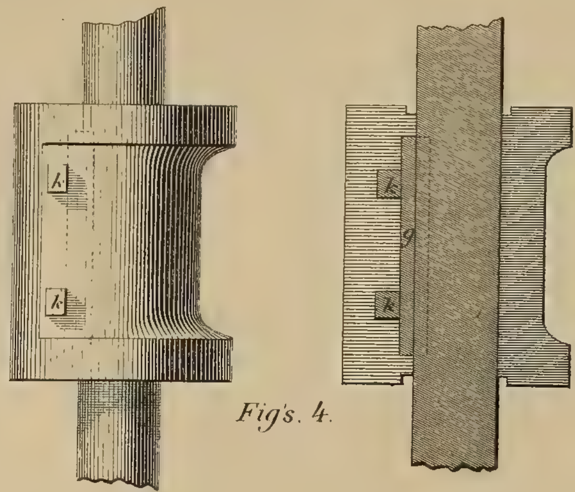
The rotary motion of the stamp, imparted by the friction of the cam against the tappet, is in very general use in Nevada. This is one of the advantages offered by the use of round shoes, stems, and tappets. The revolving cam, meeting the tappet, and raising the stamp, causes it while being

lifted to make a partial revolution about its vertical axis, which rotary motion being continued during the free fall of the stamp, produces a grinding effect between the shoe and die upon the substance to be crushed. Not only is the effective duty of the stamp at each blow increased in this way, but the shoe wears down much more evenly than when it falls without such rotary motion.

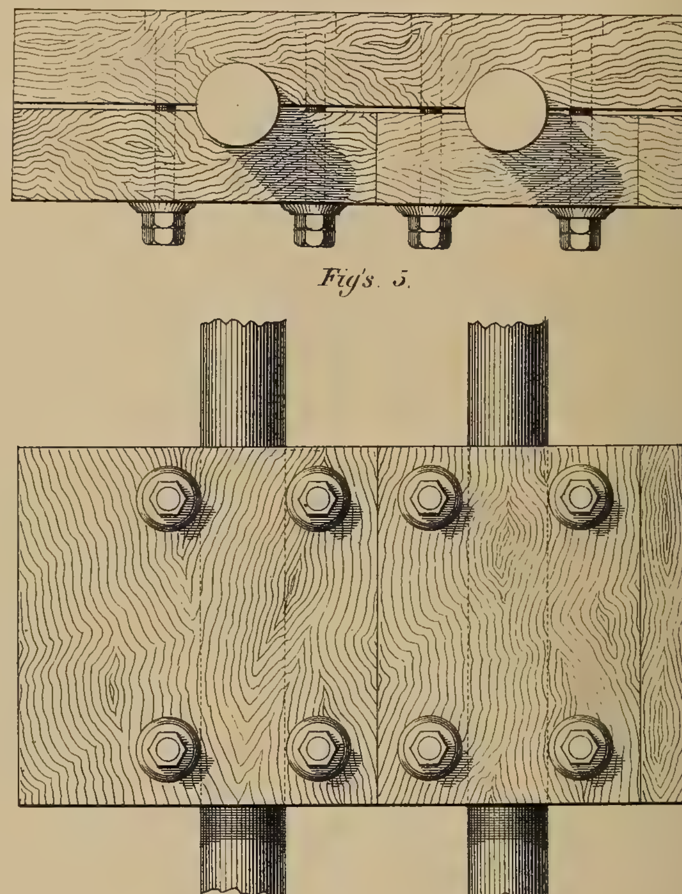
GUIDES.—The stamp is held vertically in its movement by guides, between which the stem passes. These were formerly made of iron, but such have been almost entirely replaced by wooden ones in Nevada and California. One set of guides is placed below the tappet, about a foot above the top of the mortar; the other set is placed near the top of the stem, so that six inches or a foot of the latter may project above the guides. They are supported by the cross-timbers, or ties, $G$, $G'$, which form a part of the battery frame, connecting the two uprights or posts. They are usually made of pine, though hard wood is preferred, and are from 10 to 16 inches wide. One part of the guide is made in a single piece for the whole battery, bolted to the cross-timber; the other part may be in one piece like the first, or cut into as many pieces as there are stamps in the battery, as in Fig. 5, Plate XX, which are then secured to the corresponding part by bolts. In each part are cut semi-circular recesses, which, when the two parts are put together so that the recesses correspond, the holes or stemways for the reception of the stamp-stems are formed. When the guides are so worn by friction as to permit too much motion of the stems, they may be dressed down on their adjacent faces, by which means the recesses are reduced to nearly the proper dimensions.

CAMS.—The cam is a curved arm fixed to a shaft, which is so placed in front of the battery that, by the revolution of the shaft, the cam is brought into contact with the tappet of the stamp-stem, causing the latter to rise to a height determined by the length of the cam, and to fall at the moment of its release from such contact.

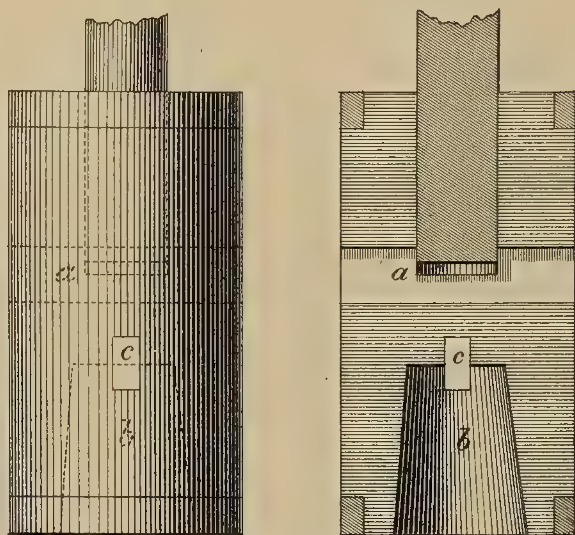
In Nevada the cams are made of tough cast iron, and are usually "double armed," that is, having two arms attached to one central hub. Figs. 6 and 7, on Plate XX, show the form of cams most generally in use; in Fig. 7, *a* is the hub, *b*, *b* are the arms, *c* is the face, and *d*, a strengthening rib.




*Fig's. 4.*



*Fig's. 5.*




*Fig's. 2.*

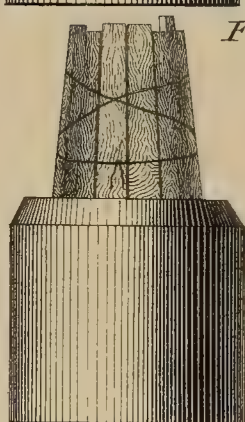
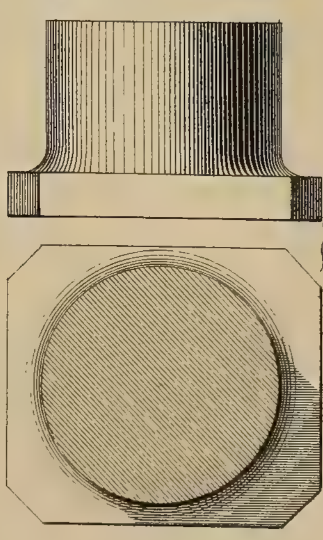
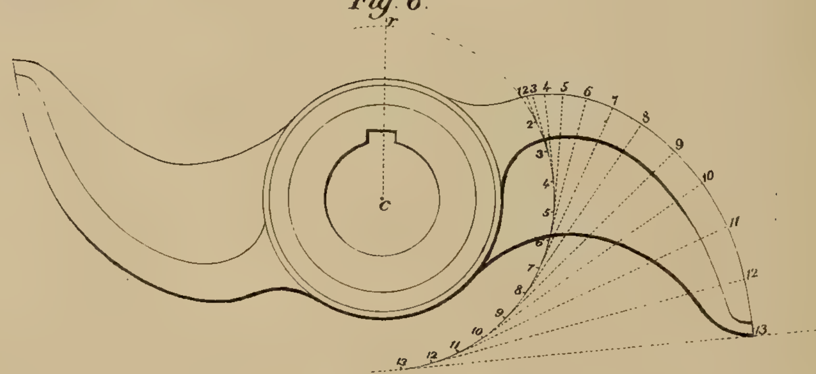


*Fig. 3.*



*Fig's. 1.*

*Fig. 6.*



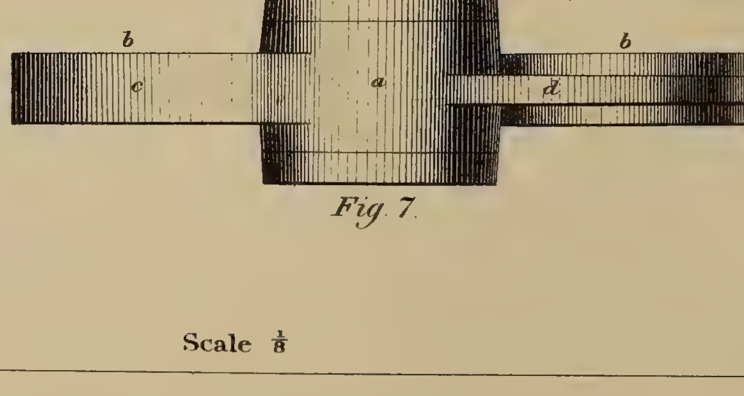




*Fig. 7.*

Scale $\frac{1}{8}$

The proper curve of the face of the cam, in order that it may perform the desired duty with the least friction, is the involute of a circle, the radius of which is equal to the distance between the center of the cam-shaft and the center of the stamp-stem. This produces a line for the face of the cam which meets, better than any other, the various requirements. The bottom of the tappet is constantly perpendicular to the radius of the curve of the cam; the tappet, and with it the stamp, is lifted vertically and uniformly, so that the lift of the stamp is always regularly proportioned to the revolution of the cam-shaft.

The cam-curve may be constructed on paper by means of tangents, as shown in Fig. 6, Plate XX. If *c* represents the center of the cam-shaft, and *c r* the distance from the center of the cam-shaft to the center of the stamp-stem, the circle described about *c*, with *c r* as a radius, is the developing circle of the involute. The distance, representing the height to which the stamp is to be lifted, is laid off upon the circumference of this circle, as from the point 1; which distance is subdivided into a convenient number of equal parts, determining, as in Fig. 6, the points 2, 3, 4, * * * * * 13. From each one of these points in the circle a tangent is drawn, on which is laid off a distance equal to the length of arc between the point 1 and the point from which the tangent is drawn. All the points thus determined in the tangent-lines are points in the cam-curve, and may be connected, as shown in the figure, thus producing the line for the face of the cam.

In practice the line of curvature is produced by cutting from a thin board a circular piece, the radius of which is equal to the horizontal distance from the center of the cam-shaft to the center of the stamp-stem. At a given point on the periphery of the circular piece is fixed one end of a thread, which must have the length of the greatest desired lift of the stamp, and to the other end of which is attached a pencil point.

The circular piece, with the attached thread wound on the periphery of the circle, is laid on a smooth board, on which the line is to be traced, and the thread, being constantly stretched to its furthest reach, is unwound until it forms a tangent to the circle at the point where the other end is attached. The line described by the pencil point is the desired curve.

Some builders slightly modify this curve, giving to the cam-arm a greater

curvature near each of its ends, in order that the cam, in its revolution, may come in contact with the tappet at the least practicable distance from the cam-shaft, where the concussion is less than at a greater distance, and to diminish the friction between the extreme end of the cam and the face of the tappet. The face of the cam is 2 or 2½ inches wide. Its extreme end is fashioned so as to correspond to the outer edge of the tappet, which is circular. The cam is placed as near the stamp-stem as practicable, without coming in contact with it. The cams are caused to revolve by means of the cam-shaft, to which they are secured by one or, sometimes, two keys or wedges.

The cam-shaft is a round shaft of iron, which is smoothly turned and finished, having one or two key-seats or grooves, cut in it lengthwise, for the purpose of securing the cams in their places. The shaft rests in boxes, which are usually supported by shoulders cut on the upright posts of the battery frame. Cam-shafts vary in diameter from 4 to 6 or 7 inches, according to the number of cams to be fixed upon them and the weight of the stamps to be raised. In some mills a single cam-shaft is made long enough to carry all the cams for as many batteries as there may be. In Nevada and California, however, short cam-shafts are in general use, a separate shaft being employed for each battery, or, in many cases, one shaft for two batteries. Separate cam-shafts are preferred, on account of the independence of each battery, so that if one be stopped by any accident to the cams or the stamps, or for repairs of any kind, the operation of the others is uninterrupted. Each shaft, in such case, is driven by its proper pulley, which receives its motion, by means of belting, from a countershaft. In the figures on Plate XIX the pulleys and belting are shown. The cam-shaft is set in motion by applying the tightening pulley to the belt.

The number of stamps in each battery is commonly four or five. The latter number seems to be preferred. The order in which they are allowed to drop is not always arranged in the same manner in different mills, but the desired conditions are that the weight of the stamps to be raised may be uniformly distributed on the cam-shaft, so that the weight of metal lifted may be, as nearly as possible, the same at any moment of the revolution, and that each stamp may fall effectively upon the material to be crushed, and, by the force of its blow, aid in the proper distribution of the stuff among its neigh-

boring stamps. If the stamps are allowed to rise and fall in regular succession, from one end of the battery to the other, the material is usually found to accumulate at one end, and the effective duty of all the stamps greatly diminished. The order must therefore be varied. In a five-stamp battery a common arrangement is to let fall first the middle stamp, then the end stamp on the right, then the second stamp on the left, then the second stamp on the right, and finally the end stamp on the left. The order in which the stamps are to fall being determined, it is carried into effect by fixing the cams on the shaft in such position that each cam, by the revolution of the shaft, will lift its respective stamp at the desired moment. For this purpose the key-seats cut in the hub of the cam must be determined with care; one common key-seat being cut on the cam-shaft, when the desired position of any given cam has been ascertained, the key-seat in the hub is cut to correspond with that of the shaft.

When it becomes necessary to hang up a stamp so that the cam may revolve without reaching the tappet, it is supported by a prop or stud, *n*, which is shown in the drawing on Plate XIX. The lower end of the studs, of which there is one for each stamp, is pivoted on a small shaft fixed across the battery from end to end, resting in boxes, which are secured to the uprights. Each stud is just long enough to support the stamp, when placed under the tappet, at a height which is about an inch above the highest lift given by the cam. To bring the end of the stud into this position, when desired, the workman lays a smooth stick on the face of the cam as it is rising to the tappet, and holds it there while the stamp is lifted. The stick is as wide as the face of the cam, long enough to be held conveniently, and an inch and a half thick at the end which comes between the cam and tappet. By this means the stamp is raised high enough for the stud to be put in place, which being done, the stamp is supported above the reach of the cam. To set it again in motion the operation is repeated, the stud being withdrawn at the moment when the stick on the face of the cam has lifted the stamp clear of its support.

In Nevada the weight of stamps in most general use is between 600 and 700 pounds. They are usually run at about 70 or 80, sometimes 90 or even 100, blows per minute; they drop from 7 to 10 inches, according to their speed, the greater number of blows per minute requiring shorter lift. In

reducing the quartz of the Comstock lode by wet crushing, discharging through a No. 5 or No. 6 screen, the average duty is about two tons in twenty-four hours. In some mills it is said to reach three tons per day. Much of the effectiveness of the stamps depends on the degree of care devoted to keeping the working parts in good condition and with the regularity with which they are supplied with ore. This is commonly done by hand labor, the rock being shovelled in at such rate as it is crushed and discharged. In some mills, however, automatic feeders are employed, which give satisfaction. These consist of a hopper, filled with ore, from which a trough or chute leads to the feed-opening of the battery, so inclined that the ore will slide down from the hopper to the battery, if the chute, which is hung on a pivot, be agitated. A rod is attached to the chute, and so placed that the tappet of the stamp, when the latter gets so low as to require an additional supply of rock, will strike its upper end, thus giving a shock which causes the ore to move down and fall into the battery.

Quantity of water used.—The quantity of water consumed in the batteries varies with the character of the ore and the degree of fineness to which it is crushed. Usually, in the mills of the Washoe district, the consumption is between 250 and 300 cubic feet per ton of rock treated, or from one-third to one-half of a cubic foot of water per stamp, per minute; but this includes the water used in the pans which does not pass through the batteries.

At the Petaluma mill the supply tank contains 4,400 cubic feet of water, which is sufficient for eight hours' work of full duty. The mill has 24 stamps, which crush 55 tons of rock per day, discharging at only one side of the mortar, through a No. 6 punched screen. The consumption, in this instance, is equal to 240 cubic feet of water per ton of rock, or $\frac{38}{100}$ of a cubic foot of water per stamp, per minute. Making a due allowance for a portion of the water used in amalgamation, without having passed through the batteries, the quantity actually used in crushing, in this mill, does not exceed one-fourth, or possibly three-tenths, of one cubic foot per stamp, per minute.

The method of measurement, in the delivery of water, is by "miners inches." A "miners' inch" is the quantity of water that will pass through an orifice one inch square in the side of the measuring box, under a head, usually, of six inches. The measurement is not uniform throughout the country, as

different heads are used in different places. Generally, however, in California the aperture is made two inches deep and as long as need be in order to furnish the requisite number of inches, and the water in the measuring box, which is at one side of the supplying flume, is allowed to attain a height of six inches above the center of the orifice.

The quantity of water that will pass through an orifice of one inch square in the side of the box, under a head of six inches, determined by multiplying the area of the orifice by the theoretical velocity $\sqrt{2gh}$, and taking two-thirds of the product as effective discharge, is .02633 cubic feet per second, 1.578 cubic feet per minute, and 94.68 cubic feet per hour. The mill just referred to uses five inches of water. Assuming that its measurement is uniformly in accordance with the above conditions, the amount delivered in twenty-four hours is 11,361 cubic feet; equal to about 206½ cubic feet per ton of rock treated. Taking the operation of this mill as a criterion, one inch of water is a supply for five stamps, including the quantity required for amalgamation as well as for crushing.

The mills of Virginia City and Gold Hill, that have no springs or other sources of water of their own, are supplied by the Virginia and Gold Hill Water Company. This company obtain water by means of tunnels driven into the hillside for the purpose, and by purchase from mining companies, whose works furnish considerable quantities. Under ordinary circumstances the supply of water, derived from sources above Virginia City and available for use there, is sufficient to meet all demands at that place; in addition to which there are more sources below the city, in the mines and lower tunnels. In seasons of drought some inconvenience is experienced.

Pans.—The common features of the grinding and amalgamating pans have already been described on a foregoing page. There are, however, various kinds of pans which, although resembling each other in general character, present some important differences in the details of construction. These differences have been gradually developed since the first introduction of the common pan, each aiming especially to meet some one or more of the various requirements of an efficient machine.

The main objects sought for by inventors have been to produce grinding surfaces of most effective form, securing the greatest uniformity of wear with

economy of power; to obtain the most favorable conditions for amalgamation, depending mainly on the free circulation of the pulp, the uniform and thorough distribution of the quicksilver, and the proper degree of heat; and to combine, with these requirements, simplicity and cheapness in construction, facility in management and repair, large capacity, and economy of time, labor, and materials in the performance of duty.

The attempts that have been made to obtain these results have met with varied success, the different devices of any one pan sometimes obtaining a high degree of excellence in certain details at the cost of it in others.

Among the differences in characteristic features of pans the most noticeable is that of the bottom and the grinding surfaces, some being flat, and others variously curved; other details, of more or less importance, such as the construction of the muller and the method of attaching it to the driver, the form of the shoes and dies, the means of fixing them in place, of providing for the heating of the pulp and for its circulation during the grinding and amalgamating process, vary considerably in the several patterns.

The opinions of practical mill-men are somewhat divided regarding the comparative advantages of the different forms of pan-bottoms. The prevailing opinion, however, among those with whom the writer has conversed, seems to be, all things considered, in favor of the flat bottom. While other forms of grinding surfaces may possess superior advantages, theoretically, their greater efficiency, in practice, is often lost by the unequal wear of the surface of the muller, usually resulting from the difficulty of keeping the other parts of the machine, on which the grinding surfaces depend, in perfect order. The various parts of the flat muller are simpler in form, more easily handled, and more conveniently replaced when worn out. While the flat-bottomed muller involves the expenditure of more power in carrying its load of thick pulp, this disadvantage is counterbalanced, in the opinion of some, by the more complete distribution of the quicksilver and the, consequently, more perfect amalgamation.

The flat-bottomed pans of Varney and of Wheeler, and that of Hepburn and Peterson with conical bottom, have been widely used during several years past. Some improvements have been added to them lately, and they are still held in high esteem by mill-men. Within the last year or two, other makers

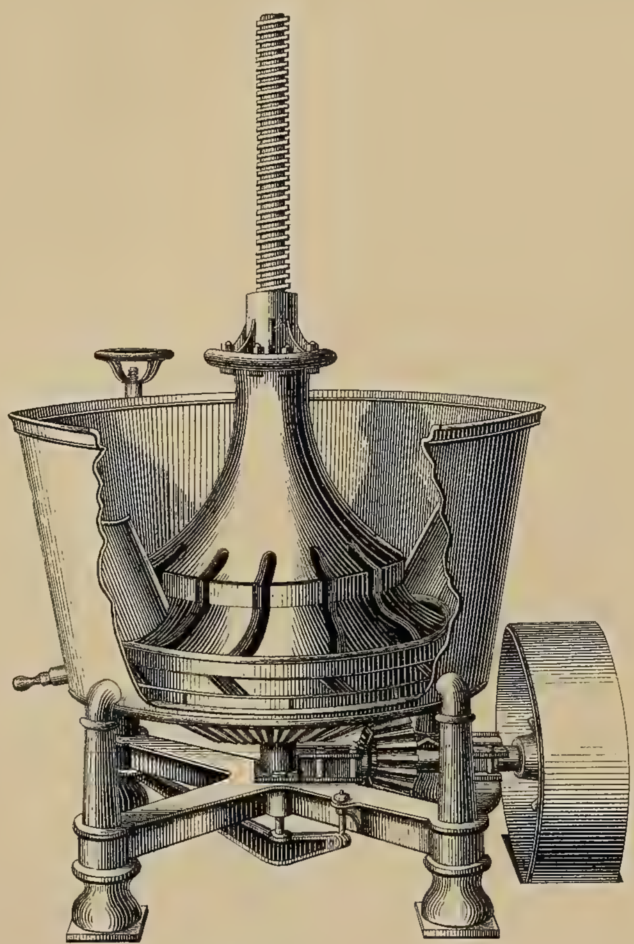


*Fig. 1.*

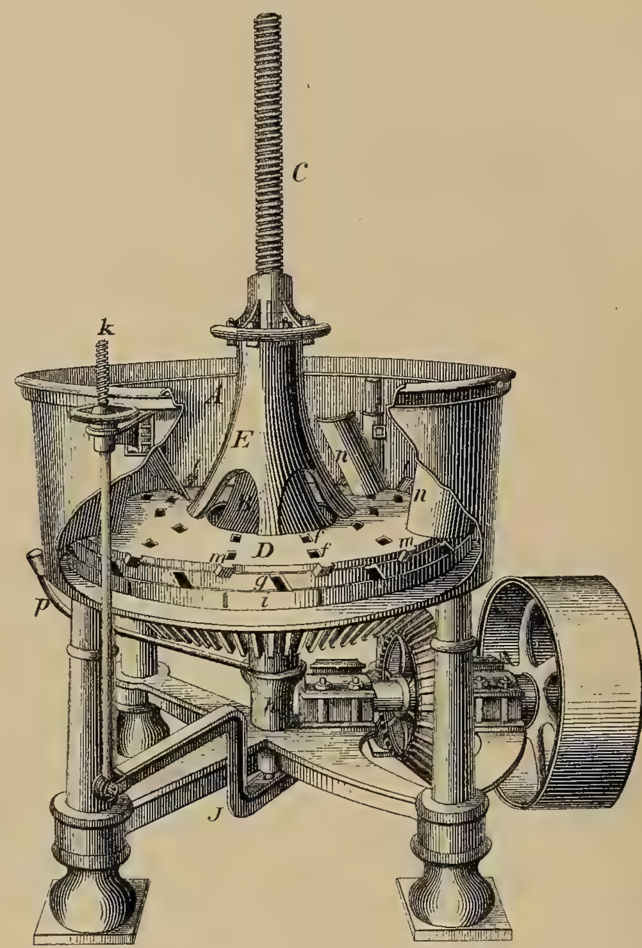



*Fig. 2.*

REFERENCE
to Fig. 2.

*A. Pan Rim.*
*B. Central Cone.*
*C. Central Shaft.*
*D. Muller.*
*E. Driver.*
*f. Aperture for attaching shoes to muller.*
*h. Step box.*
*g. Shoes.*
*i. Dies.*
*j. Lever for raising muller.*
*k. Rod for moving lever.*
*l. Projection on Pan Rim.*
*m. Similar projection on muller.*
*n. Wings attached to Pan Rim.*
*p. Oil conveyer.*

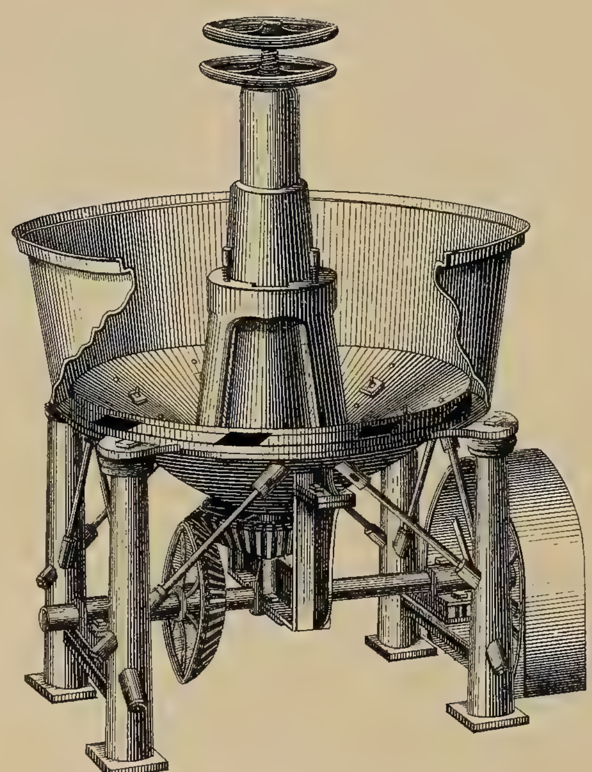


*Fig. 3.*

*Fig. 4.*

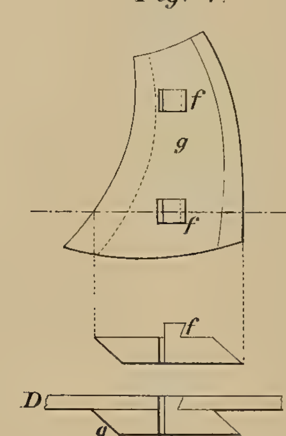



*Fig. 1. Wheeler and Randall's Excelsior Pan.*
*Fig. 2. Wheeler's Amalgamator.*
*Fig. 3. Hepburn and Peterson's Pan.*
*Fig. 4. Shoe in Wheeler's Pan.*

have introduced new pans, the characteristic features of which are great capacity and simplicity of construction. Such are the large, flat-bottomed pans of McCone, Horn, and Fountain, which, in their mechanical details, seem to combine some of the best results of the experience that has been gained since pan amalgamation was introduced, and, by their enlarged dimensions, to have the capacity for treating, in the same or nearly the same period of time, a charge three or four times as great as that treated by any of the pans formerly in use.

In the following pages a few of the pans that have been used, and are still in most favor, will be described briefly but with sufficient detail to indicate their most characteristic differences.

Plate XXI presents views of three well-known pans. They show the three different forms of pan-bottoms, the flat, conical, and conoidal. The flat-bottomed pan, Fig. 2, known as Wheeler's Amalgamator, is, perhaps, in more general use than either of the others, although Hepburn and Peterson's pan is in great favor among many mill-men.

WHEELER'S PAN.—The Wheeler pan of ordinary size is about 4 feet in diameter, at the bottom, and 2 feet, or little more, in depth. The general arrangement of the several parts of the machine may be readily seen by a glance at the drawing. *A* is the rim of the pan, in the center of which is the hollow cone, *B*, rising from the bottom, with which it is cast in one piece. Through this cone the vertical shaft, *C*, passes, which, being driven by the gearing below the pan, gives motion to the muller, *D*, by means of the driver, *E*, which is keyed to the shaft, *C*. The muller is provided, on its under side, with shoes, *g*, that form the upper grinding surface. The form of the shoes is shown in Fig. 4, on same Plate. They are attached to the muller by means of two lugs or projections, *f*, *f*, which are received in corresponding apertures in the muller-plate and securely wedged with pieces of wood. The lower grinding surface is formed by the dies, *i*, which are usually four or eight in number, covering the greater portion of the pan-bottom and secured to it in a manner similar to that by which the shoes are fixed to the muller. There is a radial slot or space between the dies which is commonly filled with hard wood. Below the bottom is a steam-chamber for heating the pulp. The vertical shaft or spindle, *C*, rests in a step-box, *h*, to which oil is conveyed by the pipe,

*p*. A vertical pin passes downward through the center of the step-box, in contact with the shaft and resting its lower end on the lever, *j*. This lever may be raised or lowered slightly by the hand-wheel, on the rod, *k*, thus raising the muller from the dies, if desired. The shaft, *C*, is also furnished with a screw by means of which the muller may be raised up entirely above the rim of the pan for the purpose of cleaning up or of changing the shoes and dies. The hoisting apparatus required in the absence of this screw is thus avoided. In order to impart an upward current or movement to the pulp there are inclined ledges, *l*, on the rim of the pan; and smaller ledges, *m*, on the periphery of the muller, but inclined in the opposite direction. The pan is also provided with wings, or guide-plates, *n*, four in number, which serve to direct the moving pulp toward the center. They are fitted into and may be removed, at pleasure, from a T-shaped projection on the pan-rim. The muller is caused to make, usually, about 60 revolutions per minute. It requires from two and a half to three horse-power. Its ordinary charge is 800 to 1,000 pounds. In some mills a still larger charge is worked. The capacity of the pan is sometimes increased by adding a rim of sheet iron so as to increase the height of the side. The treatment of the charge usually requires four hours. The shoes and dies wear out in from three to six weeks, though they are made to last longer in some mills, their duration depending greatly upon the order in which the pan and all its principal working parts are kept. On this condition the economy in the wear of iron and the efficient operation of this and other pans chiefly depend. Neglect in oiling the working parts of the running gear is apt to cause unequal wear, the vertical shaft gets loose and out of line, the grinding surfaces cease to work together evenly, and the efficiency of the pan is greatly impaired, while the costs of working are very much increased. Mill-men generally prefer a shoe and die of moderate rather than excessive hardness. The former wear out faster, but are thought to grind more efficiently. Such are usually cast of an equal mixture of white and soft iron.

Greeley's Pan.—A pan known as Greeley's, which is used in some mills and which is highly spoken of, possesses the essential features of Wheeler's, but differs from it in minor details and has larger capacity. In the Petaluma mill, where ten of these pans are employed, the charge of ore consists of 2,200 pounds.

The bottom of the pan, like Wheeler's, is flat and has a steam-chamber. The dies are cast in four quadrant-shaped pieces. In the middle of each piece, on the upper side, is a radial groove or canal, leading from the center to the circumference, which permits the free circulation of the material. A similar space is left between the two adjacent edges of the several pieces. The dies are secured to the bottom of the pan by a dovetailed or wedge-shaped projection, 5 or 6 inches long and from 3 to 4 in width, on the under side of each piece, which, fitting into a similar recess in the pan-bottom holds, them fast.

The muller is a circular plate, cast separately from the driver, to which, for use in the pan, it is connected by means of four short uprights or legs, that are bolted both to the driver and the muller. The shoes are attached to the muller-plate in a manner similar to that by which the dies are secured to the bottom. On the upper side of each shoe is a projection, wedge-shaped in horizontal section, 5 or 6 inches long and from 3 to 4 wide, which fits into an aperture of corresponding form in the muller-plate, and so placed that the smaller end of the projection follows the larger end in the direction of revolution; so that the motion of the muller tends to fix the shoe more and more firmly in its place. (See Fig. 4, Plate XXII.)

The muller, when in place, is raised and lowered, not by a lever below the step-box, as is the case in the Wheeler pan, but by a screw which passes through the hub of the driver and rests with its lower end on the top of the driving shaft. A hand-wheel at the upper end of the screw serves to turn it, raising or lowering the muller, and another hand-wheel, lower down, acts as a jam-nut to keep the muller at the desired height. When the muller is in motion it may be raised or lowered by arresting the last-named wheel. (See Fig. 3, Plate XXII.)

To clean the pan up the muller-plate is lifted entirely out by means of a block and tackle. In some mills this is conveniently supported on a truck, which moves on a railway at a suitable height above the pans. By this means the truck can be brought into position above any one of the pans from which it is desired to raise the muller, and the hoisting apparatus thus applied.

No guide-plates are used for directing the pulp, the circulation of which, without these contrivances, is very active, the pulp passing from the periphery

of the pan, at the surface, downward toward the center, producing the surface of a hollow cone, through the aperture at the base of the driver and outward through the channels and between the surfaces of the shoes and dies, to the circumference, where it rises to repeat the process. The legs or standards of the driver, connecting it with the muller-plate, promote this circulation by forcing the pulp to the center and downward between the shoes and dies. The pan is said to require about four horse-power.

VARNEY'S PAN.—This is one of the older flat-bottomed pans, that has long been in great favor with many mill-men. The points of difference between it and Wheeler's are not of very great importance. It has about the same dimensions and capacity. It has no steam-chamber, but a pipe introduces steam directly into the ore, above the muller.

The dies, on the pan-bottoms, are arranged nearly like those of the Wheeler. In this pan, and sometimes in others, the radial slots in, and the spaces between, the dies are filled with pieces of hard wood, of which the fiber is fixed vertically. The wooden surface wears slightly in advance of the die, affording a passage for the pulp, and, according to some, increasing the grinding capacity of the pan.

The shoes, of which there are twelve, are fastened by bolts to the muller. The circular plate of the muller is separate from the hub or driver, on which it rests, and which has two projections at the base by which motion is imparted to the muller. The hub or driver is keyed to the vertical shaft or spindle, by which means it is set in revolution.

HEPBURN AND PETERSON'S PAN.—Fig. 3, on Plate XXI, presents a view of Hepburn and Peterson's pan. The bottom of this pan has the form of an inverted cone, inclining toward the center, as may be readily seen in the figure. The bottom is covered by four dies of corresponding form, which are secured in a manner similar to that employed in the other pans already described. There is no steam-chamber in the bottom, steam being introduced directly. In the center of the pan a hollow pillar rises, through which the driving shaft passes. The form of the muller corresponds with that of the bottom, and at the center has an upright hollow cone, by means of which it is connected with the hub or driver. The under side of the muller is fur-

nished with shoes, between which, when attached to the muller, there is a channel or radial passage left for the circulation of the pulp. The muller also contains radial grooves between the shoes, so that, when the latter wear down, the channel may still be large enough to permit an easy movement of the material. The muller is raised or lowered by means of a screw and movable nut at the top of the hub, the screw resting on the top of the driving shaft, to which the hub is keyed. The circulation of the pulp in this pan is effected without the use of wings or guides, such as are commonly employed in other pans for this purpose. When the muller is in motion the pulp, passing between the grinding surfaces, from the center to the circumference of the pan, descends again by its own weight toward the center, on the upper side of the muller; a movement promoted by the conical shape of the muller-plate. In the use of guide-plates or wings to aid the circulation there is sometimes a difficulty experienced in the tendency of coarse sand to settle and pack firmly, if the pan is stopped for a little while, and giving much trouble in starting again. By thus dispensing with the use of wings some inconvenience is avoided. The charge of the pan is about 1,500 pounds, usually working four hours on a charge. It runs at 60 or 70 revolutions per minute.

Wheeler and Randall's Pan.—Fig. 1, on Plate XXI, presents a view of a pan known as the Excelsior, devised by Wheeler and Randall. This pan differs from those before described chiefly in the form of the bottom, which is conoidal. The object of this device is to produce surfaces of such form as to insure perfect uniformity of wear and the highest degree of grinding effect. Its efficiency, in this respect, is attested by the experience of practical mill-men. It is not, however, so generally used as the ordinary Wheeler or other pans already mentioned.

The dies, muller, and shoes have, of course, a form corresponding to that of the pan-bottom. They are secured in place in much the same way as in the Wheeler pan. There are guide-plates to assist in directing the movement of the pulp, and there are openings in the muller between the shoes for its free passage between the grinding surfaces. The gearing of the pan, step-box, and driving shaft, and means of raising the muller, do not differ materially from the common Wheeler pan. This pan is made of various sizes; the

largest is $4\frac{1}{2}$ feet in diameter, and treats 3,000 pounds of ore at a single charge. It weighs 5,000 pounds.

Within the past two or three years pans of much larger dimensions, and, consequently, of greater capacity than those formerly used, have been introduced in the Washoe district, and have, generally, found great favor among mill-men. Until lately they have been chiefly used in working tailings, to the treatment of which, as well as of low-grade ores, they are especially adapted. It is claimed in their favor that they treat a charge of ore three or four times as large as that of the ordinary pans in the same, or but comparatively little more, time, economizing thereby not only time but labor and power. One large pan requires much less machinery and fewer auxiliary parts, in its operation, than three or four smaller ones, of equal capacity in the aggregate. The attention of the workman is more concentrated, and there is a much smaller loss, proportionately, by wastage of ore, quicksilver, and other materials. While the time allowed for amalgamation is much less in the larger charge than in the smaller one, in proportion to the quantity of ore treated, the results, so far, seem to be nearly or equally as good. These considerations are of special importance in the working of low-grade ores, which can only be done profitably on a large scale and at small expense per ton, and in which the loss of a small percentage of the value is comparatively trifling in amount.

McCone's Pan.—The McCone pan, constructed by Mr. McCone, proprietor of the Nevada foundery, at Silver City, is one of this kind. Some of the details of its construction, and the method of setting it up, are shown in the drawings[1] on Plate XXII. Figs. 1 and 2 show the pan, as it is mounted on a timber frame-work, and the gearing by which it is set in operation. In Fig. 2 a portion of the pan-rim is removed to show the interior. Fig. 3 shows a vertical section and Fig. 4, a plan of the pan. In the latter a portion of the muller-plate is shown and another portion is removed, exposing the shoes and dies below. This pan is 5 feet in diameter and 28 inches deep. It is

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[1] From drawings recently made and furnished to the writer by Mr. Tyrrell, of the Nevada Foundery.

Fig. 1.

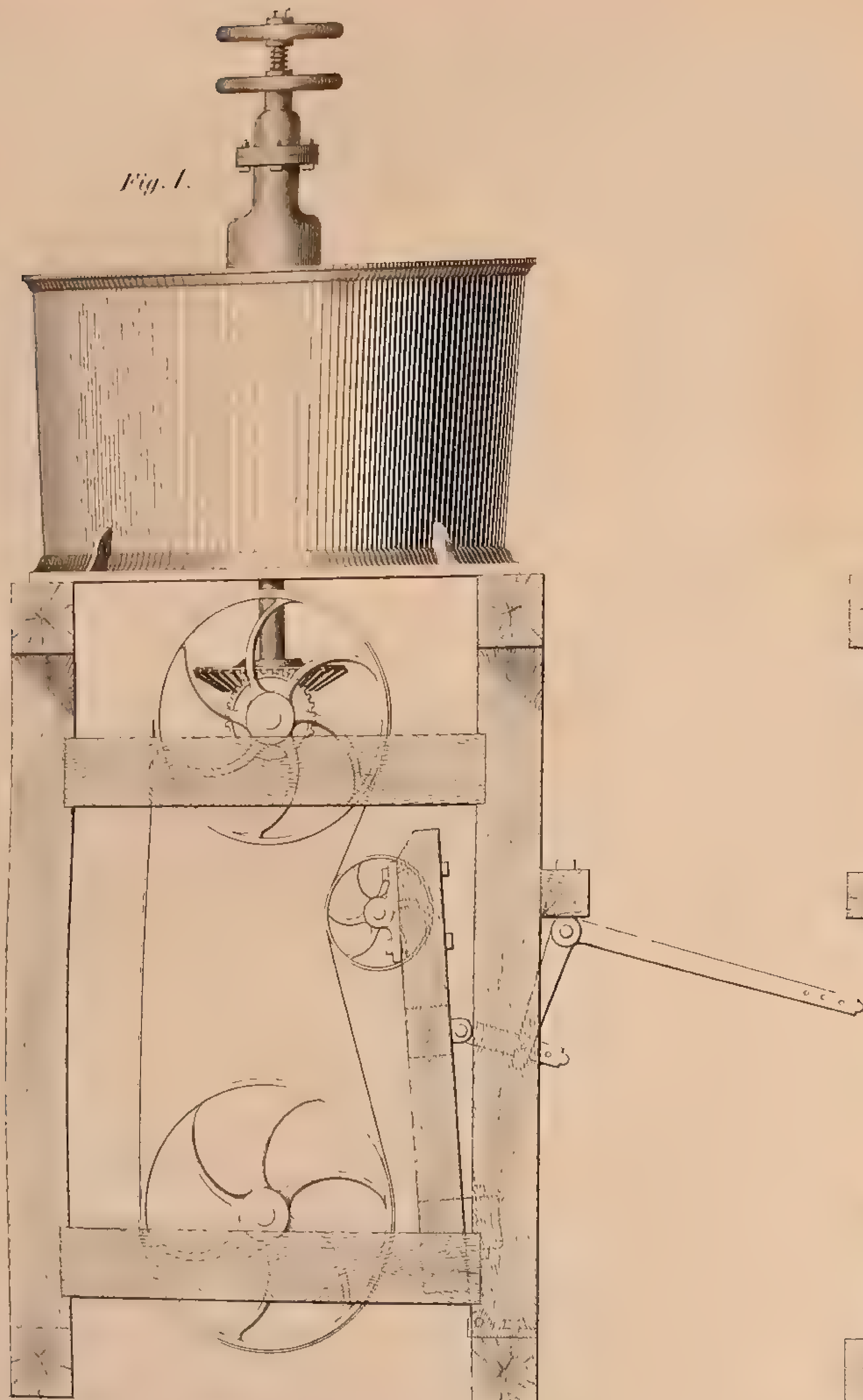


Fig. 2.

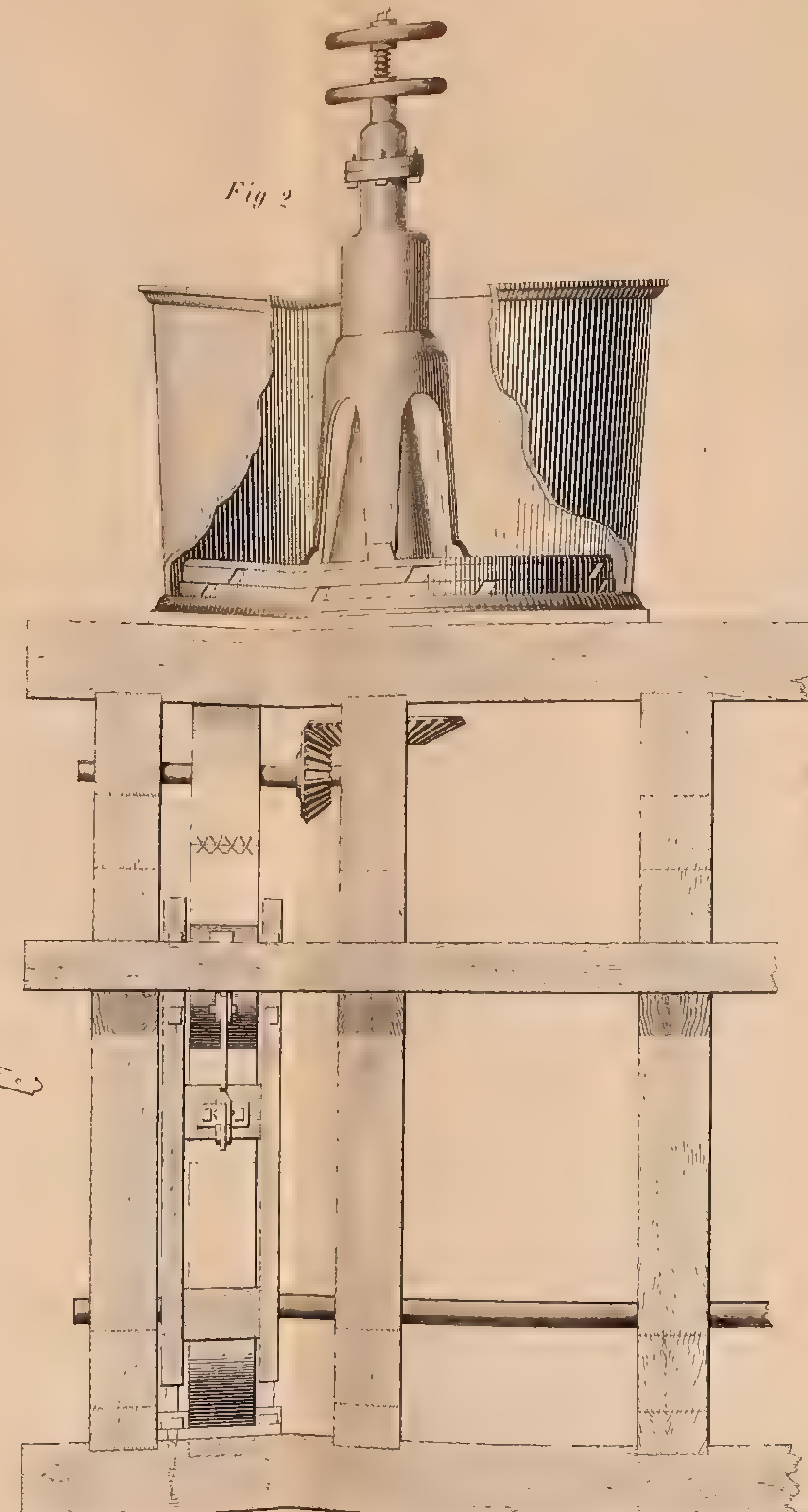
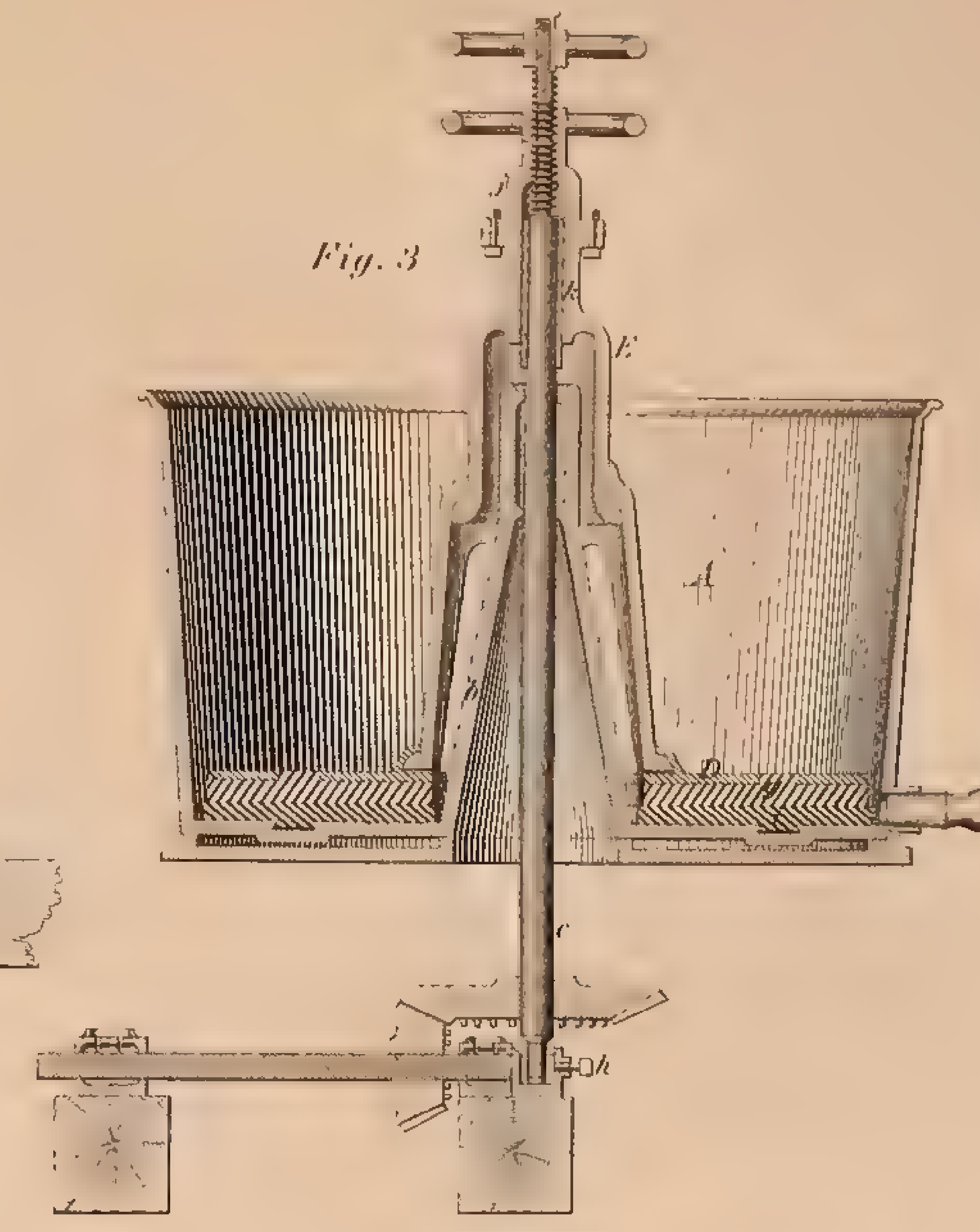


Fig. 3.



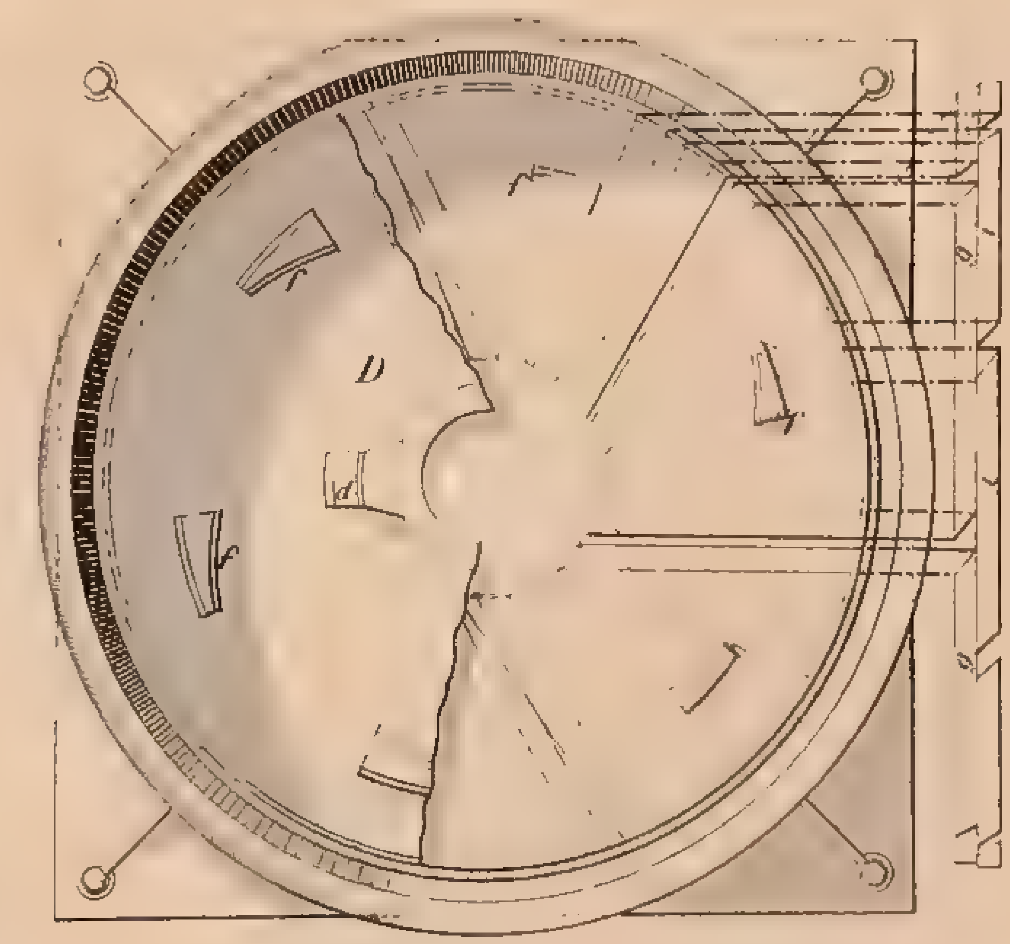




Fig. 4.

Scale: 1/20.

flat-bottomed and made either with or without a steam-chamber. When the latter is desired the false bottom is cast separately, with a rim an inch deep, and is then bolted to the main pan-bottom, thus forming the chamber. There are no standards or legs for the pan to stand upon, the bottom being a square-cornered plate of iron, projecting beyond the pan-rim, and it may be bolted directly to the timbers on which it is to rest. The bottom, with its central hollow cone, may be cast in one piece with the pan-rim, or, instead of the latter, a simple flange may be cast, corresponding in size with the rim, to which flange the rim, which may then be either a cast piece or made of sheets of iron riveted together, is bolted.

An improvement has lately been made to save the wear of the rim or side of the pan and prolong its usefulness, by placing in the bottom of the pan a false rim or circular facing for the pan-side, about nine inches deep. This is cast in segments and made to correspond in form to the rim of the pan. When fixed in place it saves the pan-rim from wear in that part which would otherwise suffer the greatest degree of friction, just as the shoes and dies protect the pan-bottom and muller-plate. When worn thin by the friction of the pulp the plates may be removed and new ones substituted for them. The driving shaft or spindle, *c*, passes up from below through the central hollow cone, *b*, but its point of support is usually independent of the pan, resting, in such case, in a step-box, *h*, which is fixed on a timber below. Some, however, prefer to have hangers bolted to the bottom of the pan and furnishing the support for the driving shaft, so that, if the foundations of the pan settle, the relative position of the several parts is more readily maintained.

The step-box is cast in one piece, with a bearing for the end of the shaft on which the vertical miter-wheel and pulley of the common driving gear are fixed.

The driver or hub, *E*, which is secured to the vertical shaft, is in two parts, an upper and lower. The upper is fixed to the shaft by two strong feathers or sliding keys, *k*. The base of the upper driver is cast with lugs, or projections, which fit into corresponding recesses in the top of the lower driver, by which means the latter is supported and set in motion. Above the upper

driver is a cap-piece, *j*, carrying the usual screw and nut arrangement for raising and lowering the muller, the bottom of the screw resting on the upper end of the vertical shaft. The lower part of the driver has three or four stout lugs, or projections, at its base, which fit into carriers on the circular part of the muller at *d*, Fig. 4. These carriers are also made to serve as the means of aiding the circulation of the pulp, as they assist in directing the current toward the center when the muller is revolving. For this purpose they are sometimes cast five or six inches high, presenting a curved surface, (not shown in the case illustrated) to the pulp and forcing it toward the center of the pan. By this means the guide-plates or wings, usually fixed to the side of the pan, but which, to some extent, obstruct the motion of the pulp, are dispensed with. Grooves for attaching guide-plates are, however, cast in the pan-rim, so that those who prefer may use them. The dies and shoes used in this pan resemble, in many respects, those of other pans. There is an inch and a half space between the outer edge of the die and the edge of the pan, and a similar space between the adjacent edges of the dies. The shoes, between which there are similar spaces, and which also have radial channels, or grooves, on their under side, to facilitate circulation, have the same radial width as the dies. The radial width of the muller-plate is a little less than that of the shoe and die, in order to allow a freer inlet and outlet to the pulp. The muller makes from 60 to 80 revolutions per minute. The pan takes 4,500 pounds of pulp at an ordinary charge, and sometimes more. It is set up very simply, being bolted to timber supports below; and is put in motion or arrested by the aplication or withdrawal of a tightener to the driving-belt, as shown in Fig. 1. The price of this pan, with its necessary gearing, pulleys, &c., is about $800.

FOUNTAIN'S PAN.—The Fountain pan and the Horn pan, each so called from the name of its inventor, have been in use two or three years. They are much alike, differing only in minor details, and both, in many respects, resemble that just described. The first-named has been changed somewhat since its first introduction. In its present form, the body of the pan is 5 feet in diameter at the top, and 4½ feet at the bottom. The bottom, rim, and central hollow pillar, are cast in one piece. A steam-chamber, when desired, is provided by

bolting to the bottom of the pan a circular plate that is cast with a rim an inch deep. The upper edge of the rim is grooved out and a round piece of rubber packing laid in the groove, which, fitting closely against the pan-bottom makes a steam-tight joint and allows for the unequal expansion and contraction of the metal. The dies are attached to the pan-bottom by means of a wedged-shaped projection as in the pan just described. The driver is cast in one long piece; its upper part, which is attached to the driving shaft by means of a key or feather, is cylindrical, and furnished on the inside with a long babbited bearing for the shaft; its lower part consists of three legs or standards, each of which has a square lug or projection at the bottom, which, fitting into a raised clutch on the muller-plate, carries and gives motion to the latter. The space between the legs or standards being open, affords free passage for the circulation of the pulp about the center. In front of each lug on the standards of the driver is an iron plate with a flaring or irregularly concave surface which, when the driver is in motion, tends to force the pulp to the center; while directly in front of this contrivance, that is, in the direction of revolution, a large piece is cut out of the muller-plate, thereby affording free passage to the pulp downward and between the grinding surfaces of the shoes and dies. Wings and guide-plates are thus dispensed with, though the pan-rim is cast with the ordinary means of attaching such plates if desired.

As the bottom of the pan is flat, and the muller has the plane-circular form, the wearing effect on the grinding surfaces is much greater near the circumference than near the center, owing to the difference in radial velocity. It frequently results from this that the shoes and dies of ordinary plane-circular grinding surfaces wear down much more rapidly at the circumference, leaving the metal thicker near the center, and so producing an uneven bearing of the muller upon the bottom and, consequently, an irregular movement.

In the Fountain pan the radial spaces between the shoes and between the dies are made wider, horizontally, near the center than they are near the circumference, so that the area of grinding surface at the circumference may be more largely in excess of that at the center than it would be if those spaces were of uniform width; thereby obviating, at least in part, the

inequality of wear. These spaces in some of the Fountain pans, are filled with wood, as already described in pans of other makers. The shoes at their circumferential edge are provided with plows to stir up the quicksilver lying on the pan-bottom. These pans work 3,000 or 4,000 pounds of sand at a single charge. Their average duty, in working tailings, is stated at ten tons per day.

SETTLERS OR SEPARATORS.—The settlers or separators (see Plate XVII) in which the quicksilver and amalgam are allowed to settle or separate themselves from the pulp, after treatment in the pan, have already been generally described on a foregoing page. They do not present so many important differences in details of construction as the pans do. They are made larger than the pans, usually having a diameter of 7 or 8 feet. They are commonly made now with a flat, sometimes concave, circular, cast-iron bottom, having a hollow cone or pillar at the center and a flange at the circumference, to which the rim, either of wood or sheet-iron, is attached. The central shaft, with its driving gear below, the screw and nut arrangement above, for raising and lowering the stirrers, and the yoke or driver fitted to the revolving shaft, are not essentially different from the similar parts of the pans. Hangers are sometimes bolted to the bottom of the settler to carry the step-box of the vertical shaft and support the driving gear; or these may rest on a timber frame independent of the bottom, as shown in the figure on Plate XVII. To the yoke or driver are attached four radial arms reaching to the circumference of the vessel. On each arm are two or sometimes three legs, terminating in a wooden shoe, variously shaped, which touches the bottom, These legs are movable radially, so that any one may be fixed at such point between the center and circumference as may be desired, and they are usually arranged at different distances on the several arms, so that in the course of each revolution each part of the surface of the bottom is passed over by one or another of the shoes.

The discharge of the separator is usually effected through outlet-holes, already described, and shown in Fig. 1, on Plate XVII. Sometimes, as in a separator constructed by Mr. Fountain, the discharge holes are placed in the central cone of the vessel, in order that it may be where there is the least

motion, avoiding thereby the loss of fine particles of amalgam or quicksilver.

The method of withdrawing the fluid amalgam or quicksilver from the vessel has already been indicated, and an ordinary contrivance for this purpose is shown in the figures on Plate XVII. Different makers vary this plan in some of the details. In some separators the groove or canal for the collection of the quicksilver is circular, concentric with the pan-bottom, and usually placed midway between the circumference of the bottom and the base of the central cone. The outlet-pipe for the discharge of the quicksilver and amalgam is connected with the bottom of this groove, leading out under the vessel to a point beyond the circumference, where it may terminate in a bowl or may turn upward and be fitted with a vertical pipe in which the outlet may be fixed at any desired height and the quicksilver allowed to discharge itself continuously as fast as it accumulates in the groove or receptacle in the pan-bottom. A cock or plug at the lowest point of the discharge-pipe permits the whole of the quicksilver to be withdrawn when desired.

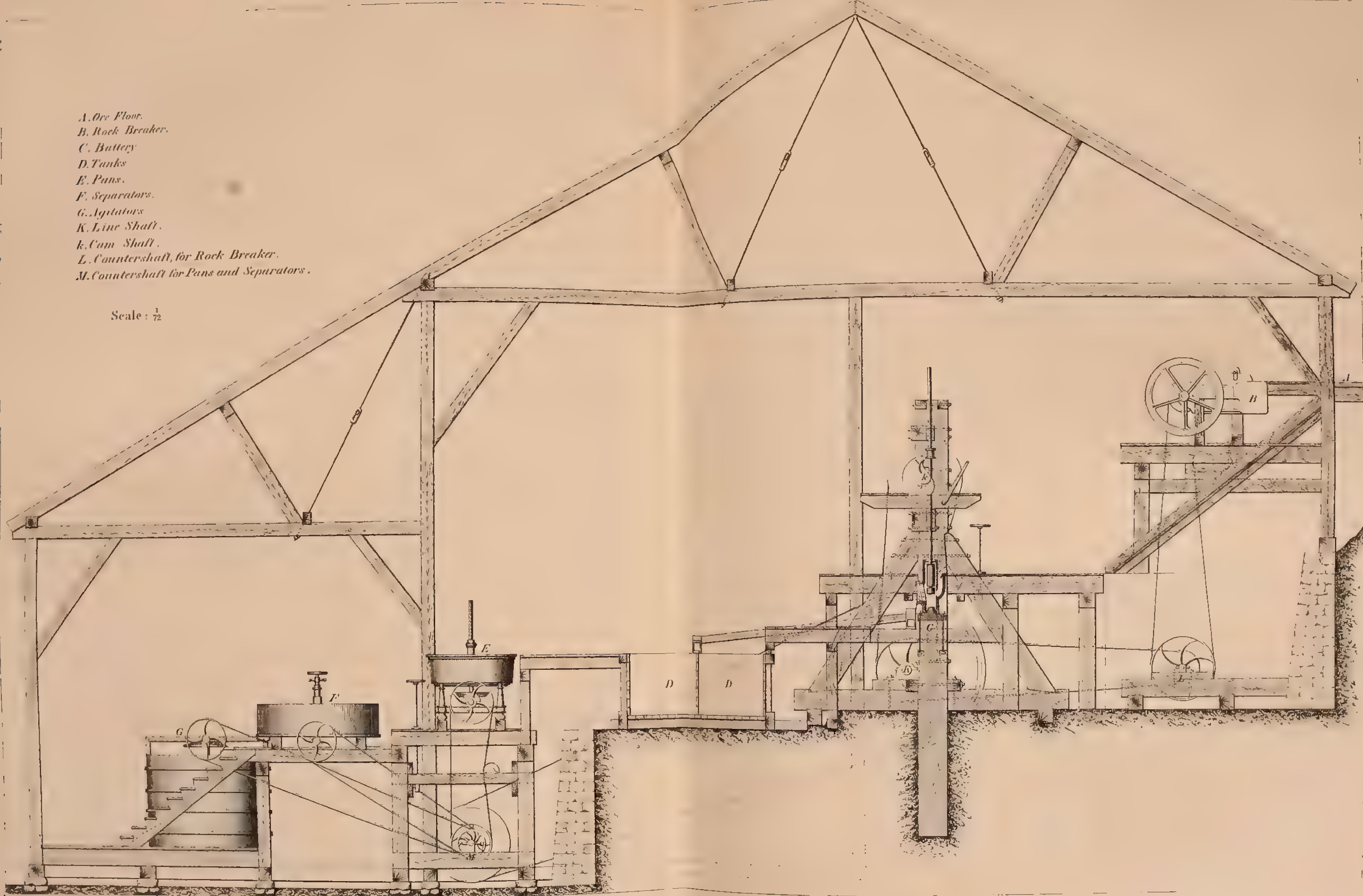
AGITATORS.—The agitators, see Plate XXIII, through which the pulp passes after leaving the separators are, in general, wooden tubs, that vary in size from 6 to 12 feet in diameter and 2 to 6 feet in depth. The main object in letting the stream of pulp pass through them is to retain and collect as much as possible of the quicksilver and amalgam and heavy particles of undecomposed ore that are carried out with the pulp discharged from the separator. A simple stirring apparatus somewhat resembling that of the separator keeps the material in a state of gentle agitation, the revolving shaft carrying four arms to which a number of staves are attached. In some mills there are several agitators, in most cases only one, and by some they are not used at all. The stuff that accumulates on the bottom is shoveled out from time to time, usually at intervals of three or four days and worked over in pans. Beyond these are a number of contrivances for concentrating the most valuable portions of the tailings. Among them are blanket sluices and other variously devised machines, some of which will receive further description in a following section when tailings and sluices will be more particularly noticed.

GENERAL ARRANGEMENT OF MILLS.—The general arrangement of the

machinery in a mill, working silver ores by the method described in the foregoing pages, may be illustrated by a drawing on Plate XXIII, which presents a sectional view of the building and the more important machines employed in it.

The batteries of stamps, as many as there may be, are arranged in one straight line. Behind them, that is on the feed side, is the breaking floor, where the rock is prepared by a stone-breaking machine, or, in its absence, by hand. When the slope of the ground permits it, large bins are sometimes constructed above and behind the breaker, into which receiver the wagons or cars bringing the ore from the mine may discharge their contents. As the outlet of the bins is on a higher level than the mouth of the breaker, the rock is delivered to that machine without much handling. Such bins, where practicable, are of great advantage in providing a reserve of ore for the mill whenever communication with the mine is interrupted for a time. The batteries discharge the crushed ore upon an apron, or, as in the case illustrated, into a trough, or launder, which conveys it to the settling tanks. These stand directly in front of the batteries, though in some mills, for lack of space, they extend along the adjacent side of the building. A platform is usually provided upon which the pulp may be deposited when shoveled out of the tanks. Some mills are so arranged as to use a car, in which the pulp is moved from the tanks to the pans. This is especially necessary when the tanks are more remote from the pans, or when the latter are arranged in a line at a right angle to the line of the batteries.

Generally the pans are arranged in a straight line, parallel to the line of batteries, as in the case illustrated. The separators stand in front of the pans, arranged in a parallel line, and on a sufficiently lower level to permit the charge of the pan to run into them. Below the separators are the agitators or other similar contrivances for the purpose of preventing the escape of quicksilver or amalgam. The power is usually communicated from the steam-engine or other motor, by gearing or belting to a line-shaft which is placed in front of, and parallel with, the line of batteries. On this shaft are pulleys, opposite to those of the several cam-shafts, to which they transmit, by belting, the power necessary for the stamps. The same shaft imparts motion, by means of countershafting and belting, to the rock-breaker and to the pans. For the latter a line of


A. Ore Floor.
B. Rock Breaker.
C. Battery
D. Tanks
E. Pans.
F. Separators.
G. Agitators
K. Line Shaft.
k. Cam Shaft.
L. Countershaft, for Rock Breaker.
M. Countershaft for Pans and Separators.
Scale : 1/72

shafting is usually arranged under the row of pans, from which shaft each pan, separator, agitator, or other similar machine may be driven by a separate pulley. The power required for each stamp of ordinary or average weight, with due allowance for friction, is about one and a-half horse-power per stamp. The power demanded by the pans is from three to six horse-power, according to their size and capacity. The expenditure of power per ton of ore crushed, ground, and amalgamated, judging by the relation existing between the power of the engines provided and the work performed by the mills, is between one and a-half and three-horse power, averaging probably about two, but varying according to the capacity of the mill and the economy with which the power is applied.

## SECTION III.

### COSTS AND RESULTS OF MILLING OPERATIONS.

Cost of Labor and Materials.—The number of men employed in a well-managed mill of twenty-four stamps and ten Greeley or large Wheeler pans, having a total capacity for treatment of about 50 or 55 tons of ore per day of twenty-four hours, is as follows: Two, breaking rock and supplying the feeders, both by day; two feeders supplying the stamps, one by day and one by night; three tankmen discharging the tanks and supplying the pans, each working eight hours; two amalgamators; two helpers; two engineers, one each by day, and one each by night; one foreman and one mechanic—in all fifteen men.

The price of labor varies from $3 50 to $6 per day, averaging, perhaps $4 50 per day for the several classes employed in the mill. The cost of labor per ton of rock treated, would, however, reach a somewhat higher figure in the course of a year than is indicated by the foregoing list of employés, owing to unavoidable loss of time for repairs or other hinderances, which diminish the actual capacity of the mill. The average cost of labor, per ton of ore, is from $2 to $3. The other chief elements of cost in the operation of a mill are iron, consumed in wear of castings for stamps and pans, averaging about $1 per ton; quicksilver, consumed or lost in the amalgamating process, of which the amount is rarely less than one pound and frequently one pound and a-half per ton, costing about $1; fuel, the cost of which varies from $6 to $16 or $18 per cord, according to the distance of the mill from the source of supply, and varying therefore from $1 to $3 per ton; water, when purchased from the Virginia and Gold Hill Water Company, at about $100 per inch, costing from 30 to 40 cents per ton of rock,[1] in mills of fair average duty; other materials and incidental expenses making in the aggregate an important item; and finally, transportation of the ore from the mine to the mill, varying from $1 to $4 per ton, which, if not properly an item of milling expense, enters into the account as an offset to cheap fuel or water-power, which can only be had at a considerable distance from the mines.

[1] The Petaluma mill uses five inches of water, for which it pays $500 per month, treating 1,650 tons of ore; equal to a cost of thirty cents per ton of ore for water.

The foregoing may be illustrated by some of the statements that follow, showing the details of cost in two mills. The first statement concerns one of the best mills in the district, situated between one and two miles from the mine supplying the ore. The transportation of the ore in this instance averages about \$1 50 per ton. The mill is driven by steam, and pays \$12 per cord for wood. There are twenty stamps and twelve Wheeler pans. The capacity of these is between 35 and 40 tons per day, for days actually worked. During the six months to which the figures apply, 6,019 tons were treated in 168½ days' work, an average of nearly 35¾ tons per day; the remaining 15½ of the 184 days the mill was idle.

The costs were as follows:

| | |
|---|---|
| For labor, per ton | \$2 37 |
| For wood, per ton, $\frac{1}{6}$ of one cord | 2 00 |
| For quicksilver, per ton, $1\frac{4}{5}$ pounds | 1 15 |
| For castings, per ton, $6\frac{3}{5}$ pounds | 60 |
| For sulphate of copper, per ton, $1\frac{3}{4}$ pounds | 27 |
| For oil | 12 |
| For hauling and sundries | 2 51 |
| Total, per ton | 9 02 |

During the six months next ensuing, the cost, per ton, for treating 6,539 tons, was \$8 33.

The statements just given are drawn from accounts made in the year 1867; but for the mills of the neighborhood referred to the costs of performing the same kind of work have not been much, if at all, diminished since that date.

The following statement presents carefully analyzed accounts of milling costs in the Savage mill, one of the two belonging to the Savage Mining Company, and employed in treating ores from the Savage mine. This mill is situated in Washoe Valley, fourteen miles from the mine. Unlike the case previously referred to, this mill has the benefit of cheap wood, costing \$6 per cord, and a partially sufficient water-power; advantages obtained at the

cost of long transportation of the ore, involving an expense for that item of not less than $4 per ton, and sometimes more. An additional disadvantage is the liability to long-continued interruption in the work, owing to the impassable condition of the roads during bad weather, stopping the supply of ore, and diminishing the earnings of the mill, while some of the expenses must of necessity continue. Thus, during the months of January, February, and March, 1868, no ore was received from the mine or crushed; and the total loss of time by the stamps or crushing machinery, owing to this and other causes, was 150 days during the whole year. The pans lost during the same year 118 days.

In the following year, the stamps lost 195 days, while the pans lost 180 days.

The power is supplied by a 28-foot water-wheel, and an engine of 16-inch cylinder. The capacity of the stream is unknown to the writer, and the proportion of power furnished by the wheel is uncertain; but as about five cords of wood per day were consumed, on the days of actual running, the engine must act an important and indispensable part in the operation of the mill.

The mill has sixteen stamps weighing each about 700 pounds, and twelve Wheeler pans. The method of operation corresponds in its essential features with the general description already given.

SAVAGE MINE.

*Detailed statement of Milling Cost for the years ending June 30, 1868 and 1869.*

| | 1868. | | 1869. | |
|---|---|---|---|---|
| Number of tons reduced | 7,740 | | 6,440 | |
| | Per ton. | Per ton. | Per ton. | Per ton. |
| Officers and general labor | ... | $0 60.7 | ... | $0 52 |
| Driving power: | | | | |
| Labor | $0 60.6 | | $0 65.8 | |
| Wood | 86.4 | | 93.4 | |
| Sundries | 08.2 | 1 55.2 | 09.3 | 1 68.5 |
| Preparing ore for batteries | ... | 22.4 | ... | 25 |
| Batteries: | | | | |
| Labor | 21 | | 23 | |
| Castings | 20.2 | | 21 | |
| Sundries | 03.3 | 44.5 | 04 | 48 |
| Amalgamating: | | | | |
| Labor | 71 | | 67.7 | |
| Castings | 77.3 | | 61.3 | |
| Salt | 07 | | | |
| Sulphate of copper | 17 | | 13 | |
| Quicksilver | 90 | 2 62.3 | 78 | 2 20 |
| Repairs: | | | | |
| Labor | 63.6 | | 26.1 | |
| Sundries | 50 | 1 13.6 | 12 | 38.1 |
| Incidental | ... | 38.9 | ... | 49 |
| Total cost for labor | 2 99.3 | | 2 59.6 | |
| Total cost for material | 3 59.4 | | 2 92 | |
| Total cost for incidental | 38.9 | | 49 | |
| | 6 97.6 | 6 97.6 | 6 00.6 | 6 00.6 |
| Hauling ore | ... | 4 28.4 | ... | 4 06 |
| Total for hauling and milling | ... | 11 26 | ... | 10 06.6 |
| Received from tailings | ... | 3 63 | ... | 1 67.6 |
| Net cost | ... | 7 63 | ... | 8 39 |

It appears, from the foregoing, that the actual costs of milling in the mill referred to were $6 per ton in 1869, and $6 97 in the year 1868, not including anything for hauling of the ore.

The writer is not in possession of similarly detailed accounts of the costs

of such work in mills where water-power only is employed, but it is said by managers of such mills to be between $5 and $5 50 per ton, not including hauling.

The hope for the future is to reduce these costs to a still lower figure; and it is not improbable that by increasing the capacity of the mills, and using large pans, that low-grade ores, demanding less nicety in treatment than is necessary for those of better quality, may be milled for $4 per ton. Indeed, it is the expressed opinion of some of the most experienced mill-men in the district, that such ores may be treated in steam-mills at the last-named figure, by the aid of the advantages conferred by the new railroad, cheapening transportation of both ore and fuel; with the further benefit to be derived from a reasonable reduction in costs of labor.

In the account just given of the cost of operations for two years of the Savage mill, it will be observed that the bullion produced from the tailings is subtracted from the total cost of milling, apparently reducing the expense of working by $3 63 per ton in 1868, and $1 67 per ton in 1869. This is, in fact, no reduction of the costs; it is simply an addition to the product that had already been derived from the first treatment of the ore by the regular process. In the case of a custom mill, receiving a fixed price for working ore and returning to the customer a certain percentage of its assay value, previously agreed upon, the tailings become the property of the mill; and whatever may subsequently be extracted from them, accruing to the mill owner, actually diminishes, by the amount of such product, the expenses of his business, and, so far, the costs of milling per ton. In the present case, while the product of the tailings does not reduce the working costs actually, it does so relatively; that is, the cost, to the mining company, of working ore in its own mill, as compared with the cost of having it worked in custom mills, is not only lessened by the difference that exists between actual costs and the miller's price, but still further diminished by whatever value may be obtained from the treatment of the tailings, amounting, in the present instance, as we have just seen, to $3 63 per ton in 1868, and $1 67 per ton in 1869, for every ton of ore worked. This will, perhaps, be more clearly understood when the location of the mills, their relation to the mines, the methods of sampling and determining the assay value of the ores, and the relation of that value to the yield obtained by milling, have been more fully set forth.

Relation of Mines to Mills.—The mills working on the Comstock ores are located at various distances from the mines, some being in the immediate vicinity, while the most remote are from thirteen to fourteen miles away. The several cañons or ravines of the Washoe hills, leading down from the croppings of the vein, where the hoisting works of the mines are situated, to the valley, 1,500 or 1,800 feet below, are all occupied by mills, thirty-five or forty in number, that are within a radius of three miles, or at an average distance of one and a half miles from the supply of ore. These are all driven by steam-power. More remote from the mines, but nearer to the sources of fuel, are other mills, some driven by steam, some by water, and some by steam and water combined. On the Carson River, distant from seven to ten miles from Virginia City, are a dozen or more mills, whose position gives them the advantage not only of cheap fuel but also of water-power, either partly or wholly sufficient for their demands. In Washoe Valley, lying west of the Washoe hills, and separating them from the Sierras, are eight or nine mills, some of them likewise enjoying the advantages of a partly sufficient water-power and cheap fuel, but situated at a distance of fourteen miles from the mines, and incurring consequently a great expense in the transportation of the ore.

The comparative advantages of these different locations so nearly counterbalance each other in a long-continued period of operations that it is perhaps difficult to pronounce decidedly in favor of either, at least under conditions existing previous to the completion of the railroad. The first-mentioned class of mills, while paying dearly for their motive power and supply of water for milling purposes, have, on the other hand, the advantage not only of cheaper hauling, but, owing to their proximity to the mines, a steadier supply of ore. Some of the distant mills, especially those that have water sufficient to enable them to dispense with steam altogether for purposes of power, may diminish the actual cost of reduction of the ore sufficiently to more than counterbalance the additional cost of hauling, but they are sometimes liable to loss of time on account of impassable roads or other obstacles that interrupt the constant supply of ore, and a few days of idleness will more than absorb the profits of a month's work.

Nearly all the mills of the district are "custom mills;" and the greater

part of the ore produced from the various mines is worked in such. "Custom mills" are those that receive the ore from the producer, work it at a fixed price per ton for treatment, and return to the customer a certain percentage of the value of the ore, the latter having been previously determined by assays. This price for working ores during two or three years past has varied between $13 and $15 per ton, including the cost of hauling the ore from the mine to the mill. Quite lately it has been reduced somewhat, though during 1869 the average was but little, if at all, below $13. Since the beginning of the present year, according to late advices from Virginia City, some of the mills of the district have reduced the price to $9 per ton. Some of the large producing mines also own mills, but seldom of capacity sufficient to meet all their demands. Thus the Savage mine in the year ending July 1, 1868, treated 16,810 tons of ore in its own mills and 67,815 tons in custom mills. The ores are carefully sampled, both before delivery to the mill and after crushing at the mill, as will be explained in more detail below, and a return of sixty-five per cent. of the assay value is required of the mill owner. Falling short of this in bullion, the mill is bound to make good the deficiency, while any excess obtained by so much of the process of treatment as has been already described in this chapter belongs also to the mine or customer. Some mills, as may be seen by the tabular statement further on, make returns as high as seventy per cent. or even more, but, as might naturally be expected, the average return of the mill to the mine does not much exceed the requirement. The residue, or "tailings," of the ore, after it has passed through the separators, belongs to the mill, and this is in many cases made to yield a good result on reworking. It is, therefore, the interest of the mill owner, when working at a fixed price per ton, to treat as many tons as possible and to return no more bullion in excess of the required standard than may be necessary in order to maintain a good reputation among competing mills. Sixty-five per cent., therefore, does not fairly indicate the percentage of value actually extracted from the ore, and is not a fair criterion by which the efficiency of the process may be judged.

Sampling the Ores.—As the mill is required to return to the mine a certain percentage of the value contained, it is necessary to have the ore carefully sampled and assayed beforehand in order to get at a basis of set-

tlement. This cannot be accomplished without some trouble and expense, a large number of assays being necessary in order to obtain a reliable average result. For this purpose the Savage Mining Company follow a very careful system, and have assays made of a double set of samples of every lot of ore. One set of these samples is taken from the wagon, taking the ore from the mine to the mill, the other is taken from the mill after the ore has been crushed.

The wagon sample is obtained by drawing from every wagon load of ore dispatched to any mill a sample of the rock, keeping distinctly separated from each other the samples of the ore sent to different mills. Each of these samples is assayed, or, sometimes, a number of samples of loads that were all sent to the same mill during one day are mixed together and the assay taken from the mixture. The mill is then charged daily with the weight of ore and the amount of gold and silver represented by the assay.

The mill sample, which is to serve as a check on the wagon sample, is usually taken by allowing the crushed ore as it comes from the battery to run into a pail or other suitable vessel, which is held or placed at the end of the trough or apron leading from the batteries to the tanks. A sample is taken in most mills every hour, in some more frequently, and the accumulated samples taken during a single day are well mixed together and dried. From this mixture a sufficient quantity is drawn for assay.[1] Where there are several batteries they may be selected alternately for sampling, or samples may be taken from each battery separately.

[1] The Savage Mining Company have an assay department for the purpose of assaying ores and bullion. The following statements, taken from this company's last annual report, furnish an interesting exhibit of the extent of this business, the kind and quantity of materials consumed, and the average cost of assays:

*Assay department, for Ore, from October* 5, 1868, *to July* 1, 1869.

| Materials consumed. EXPENSE. | Cost value. |
|---|---|
| Crucibles, 554 | $98 43 |
| Crucible covers, 640 | 87 50 |
| Muffles, 3 | 3 00 |
| Charcoal, 1,564 bushels | 544 16 |
| Acid, nitric, 59 pounds | 31 38 |
| Bi-carbonate of soda, 329 pounds | 35 31 |
| Bone ash, 196 pounds | 36 70 |
| Litharge, 350 pounds | 53 00 |
| Salt, 400 pounds | 21 75 |
| Granulated lead, 4 pounds | 1 50 |
| Mattrasses, 6 | 1 50 |
| Clay melting furnace, 1 | 25 00 |
| Cupel rack, 1 | 5 00 |
| Iron pans, 12 | 6 00 |

The wagon samples and mill samples always differ somewhat in yield, and the former is usually the higher in value. It is reasonable to believe that the finely-crushed material being intimately mixed by the process, should furnish a fairer average; nevertheless the value of the mill sample depends very much on the manner in which it is taken. Not only may it chance that the sample is caught just after an unusually rich or poor shovelful of ore has been supplied to the battery, but accident or neglect of proper precaution may affect the value of the assay. The dish or vessel placed to catch the crushed

| | | |
|---|---|---|
| Iron mortars, 3 | | $20 00 |
| Scorifiers, 6 | | 88 |
| | | 971 11 |
| Labor and materials in repairs | $115 70 | |
| Printing and stationery | 41 33 | |
| Sundries | 35 50 | |
| | | 192 53 |
| Salary of assayer | | 1,400 00 |
| | | 2,563 64 |
| Deduct cash received for assaying ore for outside parties | | 242 25 |
| Total net expense | | 2,321 39 |

Number of assays made, 4,020. Cost of assaying, $57\frac{3}{4}$ cents for each assay.

*Assay department, for Bullion, from July 1, 1868, to July 1, 1869, (12 months.)*

| Materials consumed. EXPENSE. | | Cost value. |
|---|---|---|
| Crucibles, 52 | | $247 63 |
| Crucible covers, 7 | | 15 29 |
| Muffles, 4 | | 6 72 |
| Annealing cups, 50 | | 8 50 |
| Charcoal, 3,809 bushels | | 1,328 15 |
| Borax, 1,302 pounds | | 355 42 |
| Resin, 255 pounds | | 16 32 |
| Bone ash, 73 pounds | | 14 60 |
| Lead, 25 pounds | | 5 00 |
| Acid, nitric, 217 pounds | | 119 98 |
| Acid, sulphuric, 18 pounds | | 10 94 |
| Acid, muriatic, 7 pounds | | 4 55 |
| Kerosene, 5 gallons | | 3 00 |
| Buck gloves, 24 pairs | | 37 00 |
| | | 2,173 10 |
| Labor and materials in repairs | $194 71 | |
| United States license for assaying one year, ($500 currency) | 364 61 | |
| Sundries | 38 00 | |
| | | 597 32 |
| Salaries of assayers and melters | | 6,007 15 |
| | | 8,777 57 |
| Deduct cash received for assaying bullion for outside parties | | 36 75 |
| Total net expenses | | 8,740 82 |

Bullion assayed, 1,099 bars—Nos. 831 to 1,929, inclusive.
Value, $1,949,925 17.
Cost of assaying, $\frac{45}{100}$ of one per cent. of the value of bullion assayed.

ore should not be allowed to become more than half full, and no water should be permitted to run over, as a sort of concentration would take place immediately. It may happen that the trough or launder is placed unevenly, so that more water runs off at one side of the discharge than at the other, and unless the sample represents the whole stream its value is likely to be greater or less according to the point where it was taken. In some mills the samples are taken from the ore-tanks after the sand has deposited itself in them, either collected on the surface or drawn out from a considerable depth by means of a tryer or tube. Not only may accident determine the value of such a sample, but in the sand of the tanks the value of the slimes that have passed on without depositing themselves, and which are often quite rich, is not represented.

While making two sets of samples, the mine reserves the right to settle according to the wagon sample, but in practice both assays are duly considered and an equitable adjustment arrived at. Reclamations are not often necessary.

Milling Results.—The following tabular statements, taken from the annual reports of the Savage Mining Company for years ending July 1, 1688, and July 1, 1869, exhibit some of the results of milling operations. The tables show the assay value of the ore, both by the wagon samples and mill samples, the yield of the ore and the relation of yield to assay value, the proportion of gold and silver, both in the ore and in the bullion, and, finally, the total product in bullion of the quantity treated. The operations of each month are shown in the statements, but the figures of the tables for any single month represent the *average result* obtained during that month, not from *one* but from *all* mills employed by the company in the reduction of its third-class ore. The second-class ore treated in the last half of 1867, of which the results are also given, was all worked in one mill. It should be observed, concerning the comparatively lower percentage of value obtained from the second-class ore, as shown in the table, that, being richer, it resembles more in character the first-class ore, referred to in the commencement of this chapter, in which the precious metals are combined with zinc, lead, copper, antimony, &c., rendering the extraction of the gold and silver more difficult, and unfitting it for profitable treatment by the pan process. In the last year of the two referred to, no second-class ore was distinguished.

*Tabular statement of the Monthly Results of the Reduction of Ore, in connection with its assay value,*[1] *as determined by samples taken from the wagons and by samples taken daily from the pulp at the several mills, from July* 1, 1867, *to July* 1, 1868.

[THIRD-CLASS ORE.]

| Date. | Quantity. | | Assay value of ore per ton. | | | | | | Bullion produced. Per ton. | | | Yield, per cent. of assay value. | | | | | | Proportion of gold and silver in the ore—percentage. | | | | Proportion of gold and silver in the bullion—percentage. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Per wagon samples. | | | Per mill samples. | | | | | | Per wagon samples. | | | Per mill samples. | | | Per wagon samples. | | Per mill samples. | | | |
| | Tons. | Pounds. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Gold. | Silver. | Gold. | Silver. |
| 1867. | | | | | | | | | | | | | | | | | | | | | | | |
| July - - - | 7,683 | 1,760 | $15 48 | $37 14 | $52 62 | $15 94 | $36 61 | $52 55 | $14 06 | $22 52 | $36 58 | 90.8 | 60.6 | 69.5 | 88.2 | 61.5 | 69.6 | 29.4 | 70.6 | 30.3 | 69.7 | 38.4 | 61.6 |
| August - - | 8,071 | 0,060 | 15 72 | 37 57 | 53 29 | 14 80 | 35 18 | 49 98 | 13 40 | 21 88 | 35 28 | 85.2 | 58.2 | 66.2 | 90.5 | 62.2 | 70.5 | 29.5 | 70.5 | 29.6 | 70.4 | 37.9 | 62.1 |
| September - | 7,524 | 1,010 | 14 53 | 35 35 | 49 88 | 14 98 | 34 42 | 49 40 | 12 20 | 20 36 | 32 56 | 83.9 | 57.6 | 65.2 | 81.4 | 59.1 | 65.9 | 29.1 | 70.9 | 30.3 | 69.7 | 37.4 | 62.6 |
| October - | 7,864 | 1,670 | 13 48 | 33 32 | 46 80 | 14 06 | 33 13 | 47 18 | 11 53 | 19 98 | 31 51 | 85.5 | 59.9 | 67.3 | 82.0 | 60.3 | 66.7 | 28.8 | 71.2 | 29.7 | 70.3 | 36.6 | 63.4 |
| November - | 7,267 | 1,990 | 13 58 | 36 48 | 50 06 | 13 11 | 35 52 | 48 63 | 11 22 | 22 49 | 33 71 | 82.6 | 61.6 | 67.3 | 85.5 | 63.3 | 69.3 | 27.1 | 72.9 | 26.9 | 73.1 | 33.2 | 66.8 |
| December - | 4,506 | 1,140 | 14 30 | 40 38 | 54 68 | 14 03 | 39 05 | 53 08 | 11 93 | 25 17 | 37 10 | 83.4 | 62.3 | 67.8 | 85.0 | 64.4 | 69.9 | 26.1 | 73.9 | 26.4 | 73.6 | 32.1 | 67.9 |
| 1868. | | | | | | | | | | | | | | | | | | | | | | | |
| January - | 3,046 | 0,900 | 16 52 | 43 99 | 60 51 | 14 31 | 35 54 | 49 85 | 11 78 | 22 08 | 33 86 | 71.3 | 50.2 | 55.9 | 82.3 | 62.1 | 67.9 | 27.3 | 72.7 | 28.7 | 71.3 | 34.8 | 65.2 |
| February - | 5,582 | 0,030 | 14 87 | 38 07 | 52 94 | 14 86 | 35 03 | 49 89 | 12 28 | 22 63 | 34 91 | 82.5 | 59.4 | 65.9 | 82.6 | 64.6 | 70.0 | 28.1 | 71.9 | 29.7 | 70.3 | 35.1 | 64.9 |
| March - - | 6,287 | 0,140 | 14 26 | 37 02 | 51 28 | 14 84 | 35 29 | 50 13 | 11 79 | 23 18 | 34 97 | 82.6 | 62.6 | 68.1 | 79.4 | 65.6 | 69.7 | 27.8 | 72.2 | 29.6 | 70.4 | 33.7 | 66.3 |
| April - - | 6,098 | 1,200 | 15 53 | 39 93 | 55 46 | 16 12 | 39 07 | 55 19 | 13 24 | 26 17 | 39 41 | 85.2 | 65.5 | 71.0 | 82.1 | 66.9 | 71.4 | 28.0 | 72.0 | 29.2 | 70.8 | 33.5 | 66.5 |
| May - - - | 6,915 | 1,260 | 16 68 | 46 11 | 62 79 | 16 77 | 43 71 | 60 48 | 14 14 | 31 02 | 45 16 | 84.7 | 67.2 | 71.9 | 84.3 | 70.9 | 74.6 | 26.5 | 73.5 | 27.7 | 72.3 | 31.3 | 68.7 |
| June - - - | 7,583 | 1,920 | 19 45 | 54 32 | 73 77 | 18 19 | 48 56 | 66 75 | 15 87 | 33 68 | 49 55 | 81.6 | 62.0 | 67.2 | 87.2 | 70.0 | 74.2 | 26.3 | 73.7 | 27.3 | 72.7 | 32.0 | 68.0 |
| | 78,432 | 1,080 | 15 37 | 39 74 | 55 11 | 15 25 | 37 66 | 52 91 | 12 90 | 24 30 | 37 20 | 83.9 | 61.1 | 67.5 | 84.6 | 64.5 | 70.3 | 27.9 | 72.1 | 28.8 | 71.2 | 34.7 | 65.3 |

Allowing 7 per cent. for moisture in the ore, the average yield of the third-class ore is 72 6-10 per cent. of the actual assay value for wagon samples, and 75 6-10 per cent. by mill samples.

| | |
|---|---|
| Total assay value, third-class ore, per wagon samples, gold . . . . . | $1,204,977 46 |
| Total assay value, third-class ore, per wagon samples, silver . . . . | 3,117,570 61 |
| Total . . . . . . . . . . . . . . . . . . . . . . | 4,322,548 07 |
| Total assay value, third-class ore, per mill samples, gold . . . . . . | $1,195,869 13 |
| Total assay value, third-class ore, per mill samples, silver . . . . . | 2,953,668 70 |
| Total . . . . . . . . . . . . . . . . . . . . . | 4,149,537 83 |

| | |
|---|---|
| Bullion product of third-class ore, gold . . . . . . . . . . . . . . | $1,011,520 70 |
| Bullion product of third-class ore, silver . . . . . . . . . . . . . | 1,905,908 12 |
| Total . . . . . . . . . . . . . . . . . . . . . . . | 2,917,428 82 |

[1] The assay values of the ore, given in this and the next following table, have been computed from the assay values of 2,644 wagon samples and 2,315 mill samples.

*Tabular statement of the Monthly Results of the Reduction of Ore, in connection with its assay value,*[1] *as determined by samples taken from the wagons and by samples taken daily from the pulp at the several mills, from July* 1, 1867, *to January* 1, 1868.

[SECOND-CLASS ORE.]

| Date. | Quantity. | | Assay value of ore per ton. | | | | | | Bullion produced. Per ton. | | | Yield per cent. of assay value. | | | | | | Proportion of gold and silver in the ore—percentage. | | | | Proportion of gold and silver in the bullion—percentage. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Per wagon samples. | | | Per mill samples. | | | | | | Per wagon samples. | | | Per mill samples. | | | Per wagon samples. | | Per mill samples. | | | |
| | Tons. | Pounds. | Gold. | Silver. | Total | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Gold. | Silver. | Gold. | Silver. |
| 1867. | | | | | | | | | | | | | | | | | | | | | | | |
| July - - - | 1,133 | . . | $37 06 | $95 90 | $132 96 | $25 57 | $81 55 | $107 12 | $25 57 | $43 99 | $69 56 | 68.9 | 45.8 | 52.3 | 100.0 | 54.0 | 64.9 | 27.8 | 72.2 | 23.8 | 76.2 | 36.7 | 63.3 |
| August - - | 1,050 | . . | 36 42 | 97 55 | 133 97 | 27 83 | 92 57 | 120 40 | 29 16 | 48 05 | 77 21 | 80.0 | 49.2 | 57.6 | 104.7 | 51.9 | 64.1 | 27.2 | 72.8 | 23.1 | 76.9 | 37.7 | 62.3 |
| September - | 1,050 | . . | 32 94 | 91 12 | 124 06 | 27 50 | 93 42 | 120 92 | 28 04 | 46 51 | 74 54 | 85.1 | 51.1 | 60.0 | 102.0 | 49.8 | 61.6 | 26.5 | 73.5 | 22.7 | 77.3 | 37.6 | 62.4 |
| October - | 1,034 | . . | 38 57 | 118 21 | 156 78 | 30 33 | 110 57 | 140 90 | 31 90 | 56 65 | 88 55 | 82.7 | 47.9 | 56.4 | 105.1 | 51.2 | 62.8 | 24.6 | 75.4 | 21.5 | 78.5 | 36.0 | 64.0 |
| November - | 671 | . . | 37 46 | 121 89 | 159 35 | 29 75 | 108 72 | 138 47 | 26 28 | 52 17 | 78 45 | 70.1 | 42.8 | 49.2 | 88.3 | 48.0 | 56.6 | 23.5 | 76.5 | 21.5 | 78.5 | 33.5 | 66.5 |
| December - | 171 | 1,080 | 55 93 | 171 79 | 227 72 | 20 39 | 195 02 | 125 41 | 38 10 | 61 10 | 99 20 | 68.1 | 35.5 | 43.5 | 186.8 | 58.1 | 79.1 | 24.5 | 75.5 | 16.2 | 83.8 | 38.4 | 61.6 |
| | 5,109 | 1,080 | 37 07 | 105 75 | 142 82 | 27 77 | 96 48 | 124 25 | 28 60 | 49 56 | 78 16 | 77.2 | 46.9 | 54.8 | 103.0 | 51.3 | 62.9 | 25.7 | 74.3 | 21.5 | 78.5 | 36.7 | 63.3 |

Allowing 7 per cent. for moisture in the ore, the average yield of the second-class ore is 58 9-10 per cent. of the actual assay value for wagon samples, and 67 7-10 per cent. of assay value by mill samples.

| | |
|---|---|
| Total assay value, second class ore, per wagon samples, gold . . . . | $189,440 47 |
| Total assay value, second-class ore, per wagon samples, silver . . . . | 540,260 29 |
| Total . . . . . . . . . . . . . . . . . . . . | 729,700 76 |

| | |
|---|---|
| Total assay value, second-class ore, per mill samples, gold . . . . . | $141,888 48 |
| Total assay value, second-class ore, per mill samples, silver . . . . . | 492,981 28 |
| Total . . . . . . . . . . . . . . . . . . . . | 634,869 76 |

| | |
|---|---|
| Bullion product of second-class ore, gold . . . . . . . . . . . . . | $146,190 32 |
| Bullion product of second-class ore, silver . . . . . . . . . . . . . | 253,207 90 |
| Total . . . . . . . . . . . . . . . . . . . . . . | 399,398 22 |

[1] The assay values of the ore, given in this and the foregoing table, have been computed from the assay values of 2,644 wagon samples and 2,315 mill samples.

*Statement of Monthly Results of Reduction of Ore, in connection with the assay value,*[1] *as determined by wagon samples and by samples taken daily from the pulp, from July* 1, 1868, *to July* 1, 1869.

[THIRD-CLASS ORE.]

| Date. | Quantity. | | Assay value of ore per ton. Per wagon samples. | | | Per mill samples. | | | Bullion produced. Per ton. | | | Yield, per cent. of assay value. Per wagon samples. | | | Per mill samples. | | | Proportion of gold and silver in the ore—percentage. Per wagon samples. | | Per mill samples. | | Proportion of gold and silver in the bullion—percentage. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons. | Pounds. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Gold. | Silver. | Gold. | Silver. |
| 1868. | | | | | | | | | | | | | | | | | | | | | | | |
| July - - - | 6,732 | 690 | $17 24 | $47 52 | $64 76 | $14 64 | $40 34 | $54 98 | $12 83 | $28 44 | $41 27 | 74.4 | 59.8 | 63.7 | 87.6 | 70.5 | 75.0 | 26.6 | 73.4 | 26.6 | 73.4 | 31.9 | 68.1 |
| August - - | 4,766 | 40 | 14 80 | 40 85 | 55 65 | 14 08 | 35 95 | 50 03 | 11 94 | 26 04 | 37 98 | 80.6 | 63.7 | 68.2 | 84.8 | 72.4 | 75.9 | 26.6 | 73.4 | 28.1 | 71.9 | 31.4 | 68.6 |
| September - | 4,328 | 1,430 | 12 05 | 34 51 | 46 56 | 11 88 | 30 51 | 42 39 | 9 65 | 22 21 | 31 86 | 80.0 | 64.4 | 68.4 | 81.2 | 72.8 | 75.1 | 25.8 | 74.2 | 28.0 | 72.0 | 30.3 | 69.7 |
| October - | 4,628 | 900 | 11 05 | 31 83 | 42 88 | 9 74 | 27 63 | 37 37 | 7 84 | 19 33 | 27 17 | 70.9 | 60.7 | 63.3 | 80.5 | 70.0 | 72.7 | 25.8 | 74.2 | 26.0 | 74.0 | 28.8 | 71.2 |
| November - | 4,346 | - - | 10 57 | 29 74 | 40 31 | 9 91 | 26 38 | 36 29 | 8 09 | 19 19 | 27 28 | 76.5 | 64.5 | 67.6 | 81.6 | 72.7 | 75.1 | 26.2 | 73.8 | 27.3 | 72.7 | 29.6 | 70.4 |
| December - | 4,775 | 880 | 12 61 | 36 19 | 48 80 | 11 67 | 30 11 | 41 78 | 9 30 | 21 91 | 31 21 | 73.7 | 60.5 | 64.0 | 79.7 | 72.7 | 74.7 | 25.8 | 74.2 | 27.9 | 72.1 | 29.8 | 70.2 |
| 1869. | | | | | | | | | | | | | | | | | | | | | | | |
| January - | 4,952 | 310 | 14 40 | 43 30 | 57 70 | 12 08 | 33 15 | 45 23 | 9 53 | 22 62 | 32 15 | 66.2 | 52.2 | 55.7 | 78.8 | 68.2 | 72.2 | 25.0 | 75.0 | 26.7 | 73.3 | 29.6 | 70.4 |
| February - | 5,369 | 40 | 14 34 | 44 75 | 59 09 | 13 01 | 36 89 | 49 90 | 9 80 | 23 95 | 33 75 | 68.3 | 53.5 | 57.1 | 75.3 | 64.9 | 67.6 | 24.2 | 75.8 | 26.0 | 74.0 | 29.0 | 71.0 |
| March - - | 4,714 | 1,880 | 16 51 | 52 81 | 69 32 | 15 52 | 42 30 | 57 82 | 10 81 | 26 05 | 36 86 | 65.4 | 49.3 | 53.2 | 69.6 | 61.6 | 63.7 | 23.8 | 76.2 | 26.8 | 73.2 | 29.3 | 70.7 |
| April - - | 4,280 | 1,790 | 20 25 | 65 22 | 85 47 | 16 21 | 49 08 | 65 29 | 12 26 | 26 28 | 38 54 | 60.5 | 40.3 | 45.0 | 75.6 | 53.5 | 59.0 | 23 7 | 76.3 | 24.8 | 75.2 | 31.8 | 68.2 |
| May - - - | 3,384 | 1,310 | 21 99 | 67 61 | 89 60 | 17 53 | 52 01 | 69 54 | 12 38 | 30 09 | 42 47 | 56.3 | 44.5 | 47.4 | 70.6 | 57.8 | 61.0 | 24.5 | 75.5 | 25.2 | 74.8 | 29.1 | 70.9 |
| June - - - | 3,132 | 1,070 | 18 21 | 55 96 | 74 17 | 16 65 | 50 99 | 67 64 | 10 00 | 23 34 | 33 34 | 54.9 | 41.7 | 44.9 | 60.0 | 45.8 | 49.3 | 24.5 | 75.5 | 24.6 | 75.4 | 30.0 | 70.0 |
| | 55,411 | 340 | 15 18 | 45 11 | 60 29 | 13 44 | 37 34 | 50 78 | 10 43 | 24 21 | 34 64 | 68.7 | 53.7 | 57.4 | 77.6 | 64.8 | 68.2 | 25.1 | 74.9 | 26.4 | 73.6 | 30.1 | 69.9 |

Allowing 6 per cent.[2] for moisture in the ore, the average yield of the third-class ore is 61 1-10 per cent. of the actual assay value per wagon samples, and 72 6-10 per cent. of the assay value by mill samples.

| | | | |
|---|---|---|---|
| Total assay value, third-class ore, per wagon samples, gold . . . . . | $841,514 23 | Total assay value, third-class ore, per mill samples, gold . . . . . . | $744,898 47 |
| Total assay value, third-class ore, per wagon samples, silver . . . . . | 2,499,501 53 | Total assay value, third-class ore, per mill samples, silver . . . . . . | 2,068,917 70 |
| Total . . . . . . . . . . . . . . . . . . . | 3,341,015 76 | Total . . . . . . . . . . . . . . . . . . . | 2,813,816 17 |

| | |
|---|---|
| Bullion product of third-class ore, gold . . . . . . . . . . . . . . | $578,082 86 |
| Bullion product of third-class ore, silver . . . . . . . . . . . . . . | 1,341,521 23 |
| Total . . . . . . . . . . . . . . . . . . . . . . . | 1,919,604 09 |

[1] The above assay values of the ore have been computed from the assay values of 1,481 wagon samples and 1,466 mill samples.

[2] The allowance for moisture in the second and third classes of ore is based on the percentage of moisture actually determined in the first-class ore. This percentage in the year ending July 1, 1869, was 5 6-10 per cent., and in the year ending July 1, 1868, 6 9-10 per cent.

Relation of Yield to Assay Value.—A glance at the columns of the foregoing tables, stating the percentage of the assay value obtained by milling, will show that the yield frequently exceeds sixty-five per cent. of the contained value. This is indeed more notable in the first of the two years referred to, because in the last year the ore of this mine has not only been of lower grade but has carried with it more base mineral, rendering the extraction of the precious metals more difficult, and consequently diminishing the yield obtained.

The impression generally existing that only sixty-five per cent. of the value is obtained by pan process and that thirty-five per cent. is lost is erroneous; for the return of sixty-five per cent. is based on the result of treating the ore in the pan and collecting the amalgam in the settler; in some mills the additional product of the agitator is returned with that of the pan and settler, while in other mills this is not done, especially if the required standard of sixty-five per cent. has been already reached by pan and settler without further addition. Moreover, the return of sixty-five per cent. includes nothing of what is, or may be, obtained from the subsequent treatment of slimes and tailings; and, furthermore, it is to be considered that the ore, as charged to the account of the mill, contains an average of six or seven per cent. of moisture, for which, in the return, no allowance is made; the sample for assay, by which the return is made, being previously dried, sixty-five per cent. of the dry sample is really equivalent to sixty-nine or seventy per cent. of the wet rock.

This may be illustrated by the following data, concerning the operations of the Savage mill, during six months ending December 31, 1867.

During that time 5,830 tons were worked. The assay value of this ore was \$318,639 80 per mill samples, and \$324,206 72 per wagon samples; or \$54 65 per ton, by mill samples, and \$55 61 per ton, by wagon samples. The total yield obtained was \$220,785 17; equal to $69\frac{2}{10}$ per cent., by mill samples, and $68\frac{1}{10}$ per cent. by wagon samples. This yield was obtained by the ordinary operation of crushing, amalgamating in the pan, and collecting the amalgam in the settler; this much constituting the process to which all ore is submitted in all mills. It will be observed that the required standard of sixty-five per cent. was already exceeded by this alone, without including

the product of the tailings or allowing anything for moisture. During the six months to which these figures relate, the product in bullion from the tailings was $12,730 71; and if this be added to the yield of the ore originally obtained by the first operation, we have a total product of $233,015 88, equal to 71.87 per cent. instead of 68.1 per cent. by wagon samples; or 73.12 per cent. instead of 69.2 per cent. by mill samples. If, in addition to this, we now allow for seven per cent. of moisture on the ore, not taken into account in the assay sample to which the foregoing percentages are referred, we have an actual return of 77.27 per cent. by wagon samples, and 78.62 per cent. by mill samples.

Finally it is to be observed that the product from the tailings above given is not all that is obtained from that source. The amount here stated comes chiefly from the agitator. The stream of tailings passing from the settler, in which the bulk of amalgam is collected, enters the agitator, where much of the amalgam and quicksilver that has escaped the settler has further opportunity to deposit itself. At intervals of four or five days this vessel is emptied and the accumulations are reworked in an ordinary pan, yielding $18 or $20 per ton. The yield thus obtained is nearly $2,000 per month, and forms nearly, if not quite, all the product represented in the foregoing statement. After leaving the agitator the stream passes on, the tailings still carrying enough value to make them worth further treatment; for which purpose they are, in fact, sold by the mill to second parties, who do a profitable business in working them again; but this last product is not included in the figures already given. The yield obtained by this final working of tailings is not definitely known to the writer but is generally stated at about $5 50 per ton, which would add about ten per cent. more to the results of the process in the mill, as already shown.

Some mills claim to have obtained more than eighty per cent., and even eighty-eight per cent., of the assay value of the ore, by the ordinary methods, without including the product of the tailings or allowing anything for moisture. This, if true, is exceptional; but it is not impossible that a certain lot of ore may have contained an unusual proportion of free gold, which, while easily escaping due representation in the assay, would add greatly to the value of the bullion obtained.

The following table shows some of the comparative results of a number of different mills, all working on Savage ore at sundry times, between July 1, 1867, and March 1, 1868. The statement is furnished from the records in the office of the Savage Mining Company. The careful manner in which Mr. Bonner, the superintendent of this company, and his assistant officials have collected and preserved in comprehensive form the various results of milling and mining experience is worthy of high praise and extended imitation among others similarly engaged. The following table is but one example among many which their records afford of valuable contributions to useful or interesting statistical knowledge.

The percentage of assay value obtained stated in the table, is based only upon the amount taken from the customary process of treatment in pan and separator, without taking into account anything subsequently produced from the agitator or working of tailings, except where the contrary is specially mentioned in the appended notes.

*Comparative statement of Operations of twenty-one different mills treating ore from Savage Mine between July* 1, 1867, *and February* 1, 1868.

| Number used to designate mill. | Amount of ore in— Tons. | Amount of ore in— Pounds. | Assay value of ore per ton as per— Mill sample. | Assay value of ore per ton as per— Wagon sample. | Relative proportions of gold and silver in the ore as per— Mill sample. Gold. | Mill sample. Silver. | Wagon sample. Gold. | Wagon sample. Silver. | Yield per ton. | Yield per cent. as per— Mill sample. | Yield per cent. as per— Wagon sample. | Relative proportion in the bullion of— Gold. | Relative proportion in the bullion of— Silver. | Percentage of gold and silver obtained as per— Mill sample. Gold. | Mill sample. Silver. | Wagon sample. Gold. | Wagon sample. Silver. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 1 | 5,830 | - - | $54 65 | $55 61 | 29.5 | 70.5 | 28.5 | 71.5 | $37 86 | 69.2 | 68.0 | 36.3 | 63.7 | 85.3 | 62.5 | 86.5 | 60.7 |
| 2 | 6,720 | - - | 55 66 | 53 35 | 29.7 | 70.3 | 28.0 | 72.0 | 38 67 | 69.4 | 72.4 | 36.0 | 64.0 | 84.0 | 63.3 | 93.2 | 64.4 |
| 3 | 5,109 | 1,080 | 124 25 | 142 81 | 22.3 | 77.7 | 25.9 | 74.1 | 78 16 | 62.9 | 54.7 | 36.6 | 63.4 | 103.0 | 51.3 | 77.1 | 46.8 |
| 4 | 3,090 | 1,380 | 50 22 | 50 12 | 29.7 | 70.3 | 29.2 | 70.8 | 32 47 | 64.6 | 64.7 | 37.5 | 62.5 | 81.6 | 57.4 | 83.2 | 57.1 |
| 5 | 7,334 | 0,500 | 48 34 | 50 94 | 27.2 | 72.8 | 28.3 | 71.7 | 32 95 | 68.1 | 64.6 | 36.3 | 63.7 | 91.0 | 59.6 | 82.8 | 57.5 |
| 6 | 7,871 | 1,060 | 49 24 | 48 68 | 31.5 | 68.5 | 28.4 | 71.6 | 33 98 | 69.0 | 69.8 | 34.3 | 65.7 | 75.1 | 66.1 | 84.2 | 64.0 |
| 7 | 4,713 | 1,140 | 47 86 | 50 27 | 28.0 | 72.0 | 27.4 | 72.6 | 34 97 | 73.0 | 68.7 | 32.8 | 67.2 | 85.5 | 68.2 | 82.8 | 63.4 |
| 8 | 507 | 1,170 | 49 79 | 55 24 | 30.8 | 69.2 | 27.3 | 72.7 | 28 70 | 57.6 | 51.9 | 40.4 | 59.6 | 74.3 | 49.6 | 76.8 | 42.5 |
| 9 | 1,821 | 1,670 | 48 98 | 59 74 | 34.4 | 65.6 | 29.4 | 70.6 | 36 29 | 74.0 | 60.7 | 38.7 | 61.3 | 83.2 | 69.2 | 79.6 | 50.2 |
| 10 | 825 | 0,490 | 49 69 | 51 70 | 32.0 | 68.0 | 28.3 | 71.7 | 30 43 | 61.2 | 58.8 | 38.3 | 61.7 | 73.1 | 55.6 | 79.4 | 50.7 |
| 11 | 800 | - - | 47 58 | 54 44 | 29.2 | 70.8 | 28.4 | 71.6 | 32 24 | 67.7 | 59.2 | 35.1 | 64.9 | 81.4 | 62.1 | 72.9 | 53.7 |
| 12 | 2,744 | 1,810 | 47 27 | 53 96 | 27.0 | 73.0 | 28.6 | 71.4 | 33 34 | 70.3 | 61.8 | 37.9 | 62.1 | 98.7 | 60.0 | 81.7 | 53.8 |
| 13 | 3,618 | 1,180 | 43 04 | 47 67 | 27.4 | 72.6 | 28.2 | 71.8 | 29 37 | 68.2 | 61.6 | 35.7 | 64.3 | 89.0 | 60.4 | 78.0 | 55.1 |
| 14 | 1,544 | 0,150 | 54 37 | 46 43 | 30.5 | 69.5 | 28.8 | 71.2 | 32 94 | 60.5 | 70.9 | 36.5 | 63.5 | 72.5 | 55.3 | 90.0 | 63.1 |
| 15 | 1,500 | 0,900 | 44 37 | 51 14 | 21.1 | 78.9 | 29.9 | 70.1 | 34 47 | 77.6 | 67.4 | 41.2 | 58.8 | 151.3 | 57.9 | 92.6 | 56.6 |
| 16 | 368 | 0,310 | 48 45 | 52 56 | 29.3 | 70.7 | 28.0 | 72.0 | 35 96 | 74.2 | 68.4 | 34.1 | 65.9 | 86.3 | 69.2 | 83.0 | 62.7 |
| 17 | 298 | 1,510 | 46 25 | 52 42 | 28.8 | 71.2 | 31.3 | 68.7 | 31 07 | 67.4 | 52.2 | 40.5 | 59.5 | 94.2 | 56.2 | 76.5 | 51.4 |
| 18 | 1,116 | 0,700 | 48 37 | 52 60 | 28.7 | 71.3 | 28.1 | 71.9 | 27 94 | 57.7 | 53.1 | 37.8 | 62.2 | 76.0 | 50.4 | 71.5 | 45.9 |
| 19 | 250 | 1,920 | 44 93 | 48 63 | 24.3 | 75.7 | 27.3 | 72.7 | 32 30 | 71.9 | 66.4 | 33.0 | 67.0 | 97.3 | 63.7 | 80.0 | 61.3 |
| 20 | 250 | 0,670 | 46 24 | 58 15 | 30.6 | 69.4 | 29.0 | 71.0 | 31 40 | 67.9 | 54.0 | 42.5 | 57.5 | 94.2 | 56.3 | 80.8 | 43.3 |
| 21 | 340 | - - | 56 50 | 53 68 | 28.6 | 71.4 | 28.4 | 71.6 | 36 00 | 63.7 | 65.4 | 36.0 | 63.8 | 80.4 | 57.0 | 82.0 | 58.4 |
| | 56,656 | 1,640 | 56 62 | 59 77 | 27.8 | 72.2 | 27.8 | 72.2 | 38 27 | 67.5 | 63.8 | 36.2 | 63.8 | 87.9 | 59.7 | 82.8 | 56.5 |

| | | | |
|---|---|---|---|
| Total assay value, as per mill samples, gold | $892,213 60 | Bullion produced, gold | $784,680 86 |
| Total assay value, as per mill samples, silver | 2,315,810 07 | Bullion produced, silver | 1,383,744 54 |
| Total | 3,208,023 67 | Total | 2,168,425 40 |

## *Notes on mills referred to in foregoing table.*

No. 1. Wheeler Pan: Charge of ore 1,000 pounds; salt 3 pounds; sulphate of copper three-fourths of a pound; quicksilver 60 pounds, added after two hours' grinding. Steam admitted directly. Time in pan, four hours.

No. 2. Details as in No. 1.

No. 3. This was all second-class ore, consequently less docile. Salt is used with each charge, but only a pinch of sulphate of copper.

No. 4. Wheeler Pans: Charge of ore 1,000 pounds; 2 or 3 pounds of salt; 3 or 4 ounces of sulphate of copper; 30 to 50 pounds of quicksilver, put in when the pan is charged. Steam used directly. Time in pan, four hours.

No. 5. Chiefly Wheeler Pans: Charge of ore 1,000 pounds; salt 6 pounds to each charge; subsequently the use of salt was abandoned without affecting the result; sulphate of copper $1\frac{1}{2}$ pounds; quicksilver 75 pounds, put in after every clean-up, subsequently 35 pounds with each charge; a quantity is also kept in the separators. Steam is used directly. Time in pan, four hours.

No. 6. Hepburn Pans: Charge 1,400 pounds; no salt used; sulphate of copper, from 3 ounces to 2 pounds, put in with the charge; quicksilver 30 to 50 pounds, added with the charge. Steam used in chamber and direct. Product of the agitator, also product of reworking slimes, returned to the mine. Time in pan, four hours.

No. 7. Wheeler Pans: Charge 1,500 pounds. No salt used. $1\frac{3}{4}$ pounds sulphate of copper, added in solution; quicksilver 60 pounds, put in with the charge. Steam used in the chamber. Time in pan, four hours. Slimes, which in some mills are mixed with the sand to be worked in the pans, are never treated in this mill. The superintendent attributes to this much of the efficiency of his work, experiments having satisfied him of the evil effects of thus mixing slimes with sand. One ton of ore is thought to produce about one hundred and fifty pounds, or from seven to eight per cent. of slime.

No. 8. Pans, reconstructed Wakely; in effect, large Wheeler: Charge 1,500 pounds. No salt used. Sulphate of copper, one pound per ton of ore, added after grinding the charge one hour; quicksilver 75 pounds, added with the copper. Steam used in chamber. Time in pan, four hours. This mill having large tank capacity, the stream of pulp from the batteries has unusually protracted opportunity for settling, and, in effect, the foreman reports that the water runs from the last tank "clear enough to drink." The final tanks contain the slimes and these are mixed with the coarser sand, in the proportion of one-third of slime and two-thirds coarser sand, to be worked in the pans. Without attaching undue significance to this note, it is interesting to contrast with it the note on No. 7, and to observe that the results of

these two mills, as given in the table, are among the two extremes of good and bad work.

No. 9. Varney Pan: Charge of ore 1,200 to 1,400 pounds; salt, 3 or 4 pounds per ton of ore; sulphate of copper, three-fourths of a pound per ton of ore; quicksilver 50 pounds, added with each new charge, after the latter has been ground two hours and a half. There is always more or less quicksilver and amalgam remaining in the pan, except just after a clean-up. Steam used direct. Time in pan, four to five hours. In addition to the usual separator there is a second or supplementary vessel of similar character, the product of which, though not very important, is returned to the mine.

No. 10. Wheeler Pans.

No. 12. Hepburn Pans: Use both salt and sulphate of copper.

No. 14. Varney Pans: Use both salt and sulphate of copper.

No. 15. Old-fashioned common pan or tub. The great excess of gold in the return, as referred to the mill sample assay, is probably to be explained by some fault in the assay of that sample, since the return does not differ widely from the general average of other mills when referred to the wagon sample, in which the proportions of gold and silver are about as usual.

Nos. 16 and 21. Use the Knox pan, an older and simpler form than any of those described in detail in this chapter.

In judging of the comparative efficiency of various mills or methods by the results obtained, on a large scale, at any of the mills in question, it is important to remember that the assay, which is the only standard to which the results are referred, is not infallible.

Notwithstanding all the care exercised by the parties interested and the great number of samples selected for assay, the result, after all, is only an approximation to the truth. Some portions of a given parcel of ore may contain free gold or segregated particles of rich silver ore, which quite escape due representation in the sampling, or the contrary may occur and the value of the parcel be thus overestimated. Further, the variable amount of moisture in the ore affects the result, since the assay is of the dried sample.

Finally, the ores produce, in crushing, very variable quantities of slime, on account, partly, of the character of the gangue, some being more clayey than others, and partly by reason of the varying conditions present in the bat-

teries, the weight and speed of the stamps, the size of the screen, &c., affecting the proportion of slime produced. These slimes carry with them a certain percentage of the value of the ore, and the relative amount of slimes and coarser sand, produced in the crushing of any given parcel of ore, becomes an important element in the consideration of the results obtained, whether the former pass out of the mill without treatment or whether they are mixed with the sand and worked in pans; especially if, as many believe, the finely divided condition of the particles composing the slimes is unfavorable to amalgamation.

Without considering the various details of manipulation in the pans, it will be seen from the foregoing that the mechanical elements of the problem are quite as important, if not much more so, than the much discussed and little understood action of the chemical reagents employed in the methods of reduction of Comstock ores. The possible and probable action of these will be further noticed in the following chapter.

## SECTION IV.

### TREATMENT OF SLIMES AND TAILINGS.

The treatment of the residue, or that which remains of the ore after it has been subjected to the process already described in this chapter, is a matter of much importance. In the earlier years of operation on the Comstock lode but little attention was paid to the stream of tailings that was constantly flowing from the mills, carrying with it a considerable proportion of the original value, because it was generally assumed that the first process had extracted from the ore everything that could be obtained with a margin of profit above the costs of milling; but with the gradual improvement in methods of work and the reduction in costs of operation, the attention of mill-men has been generally turned to this subject.

Frequent reference has been made, in the course of this chapter, to the character of these residues, the way in which they are produced, and their value as a source of profit to the mills engaged in reducing the ore.

It may be repeated that the term "slimes" applies to that portion of the crushed ore which is reduced by the stamps to an exceedingly fine condition and, flowing from the batteries in the stream of running water, does not find sufficient opportunity to deposit itself in the tanks in which the coarser sands are collected, but is carried beyond them, and only settled, after a long time, either in another set of tanks or in large reservoirs. These are properly called "battery slimes," to distinguish them from the material that may be reduced to a similarly fine condition by the operation of the pan.

The term "tailings" is understood especially to apply to that portion of the crushed ore which, after having been subjected to the grinding and amalgamating process in the pan and settler, flows away from the latter, or from the agitator, and passes on out of the mill, deprived of the greater part of its valuable contents. A part of this material is in a very fine and slimy condition, but the bulk of it may be better described as a fine-grained sand. Leaving the mill the stream flows onward, and is usually subjected at once to various methods of concentration, the most common of which is the blanket-table, by which means a portion of the escaping amalgam, quicksilver, and heavier particles of ore may be extracted to be reworked, while the great mass

of material is finally collected in dams or reservoirs for still further treatment. Reservoirs for this purpose are placed at convenient points along the courses of the streams, or cañons, on which the mills are usually placed, though on account of the limited space in the narrow valleys they are necessarily small; but at the mouths of the cañons, in the level country adjacent to the foot-hills, there are a number of reservoirs of large capacity, in which everything brought down by the streams finds a resting place, and is reserved for work in the tailing mills established there.

A few paragraphs will here be devoted to a brief notice of the character of the slimes and the methods by which they are worked, the common means of concentrating tailings, and the disposition of the concentrations; and, finally, the treatment of the unconcentrated or "raw tailings."

It has already been shown that the quantity of slimes produced in crushing ore varies considerably in different mills. In some mills the proportion of slimes is thought to be about two per cent. of the ore crushed by the stamps, while in others it is said to be as high as ten per cent. This is partly due to the difference in the character of the ore or its gangue, and partly to the difference in the conditions under which the crushing takes place.

As these slimes carry with them much of the very finely crushed silver ore, their assay value is not only considerably higher than that of common tailings, but is often higher than that of the original ore. Especially that portion of the silver-bearing mineral of the ore which exists in the form of rich sulphurets, being soft and readily crushed, is liable to be reduced to an impalpably fine condition, particularly if freed from particles of quartz, that might, if present, preserve it in a coarser form, and escape with it from the battery before being reduced to slime.

AMALGAMATION OF SLIMES IN PANS.—The attempts to work slimes by ordinary methods in pans have not hitherto, or at least until recently, been followed by very satisfactory results. This has been attributed partly to the finely divided and clayey condition of the material itself, the particles of quicksilver and amalgam becoming coated with an adhering film of the slimy substance, preventing amalgamation and involving great mechanical loss of quicksilver; partly, also, to the probable existence of the silver in the form of sulphurets, as just indicated—a combination resembling that of the first-class

ores, which require to be roasted with salt, chloridizing the silver and preparing it for amalgamation. This roasting process, however, has hitherto been too expensive to be used profitably in working slimes. Owing to these difficulties the slimes produced in crushing have not been, at least until lately, a source of much profit. In some mills, as has been already stated, it has been the custom to mix a part of the slimes with the sand of the tanks, or, in other cases, with common tailings, and so work them over in pans; but the data are not sufficient to furnish any reliable estimate of the degree of efficiency attained in extracting their valuable contents. In other mills the stream bearing the slimes has been allowed to run off with the common tailings, finding its way to the grand reservoirs at the mouths of the cañons, while others have accumulated them in dams, made specially for that purpose, holding them in reserve for a time when they might be turned to some account.

Within a year or two past much progress has been made in working these slimes in pans without previous roasting, and several mills of considerable capacity have been devoted exclusively to this business, purchasing their supply of slimes from neighboring crushing mills, and treating them in such manner as to obtain a fair percentage of their value with considerable profit.

The Messrs. Janin and Mr. Ira S. Parke have mills of this description, in Six-Mile Cañon, not far below the large mill of the Gould and Curry company.

The method of treatment employed in working slimes in these mills does not differ much, in mechanical details, from that by which the fresh ores are worked, the most notable feature of the process being the use of much larger quantities of chemical reagents than is customary in milling ordinary ore. The reagents themselves do not differ in kind, but the quantity is increased to an extent which makes it possible to believe in their efficient action.

In the Janin mill there are four McCone pans. These each receive 2,500 pounds of slime at each charge.[1]

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[1] The charge of ore for this pan is 4,000 or 5,000 pounds, but as slimes increase greatly in bulk on the addition of water, it will not take more than 2,500 pounds of the dry material.

Twelve pounds of the sulphate of copper and thirty-six pounds of salt are put into the pan with each charge, and the whole is worked for two hours before putting in the quicksilver. Little or no grinding is required, as the material is already exceedingly fine; the muller is raised high enough above the bottom to avoid unnecessary friction, but is revolved at about the same speed as in working ore, the main object being to keep up a rapid and perfect circulation of the pulp. After two hours the quicksilver is added, and in large quantity, usually 300 pounds. The charge is then worked for four hours longer, and afterward drawn off into the settler, from which the amalgam is collected in the manner already described, while the residue is allowed to pass through large agitators, before finding its way to the tailing stream, in order to save as much as possible of the escaping amalgam and quicksilver.

The quantity of quicksilver employed in this process is so large that the loss of that metal in the operation is proportionally great, especially as it is believed that the clayey condition of the slimes greatly facilitates its escape. This loss is stated at about five pounds of quicksilver to the ton of slimes. This item, together with the cost of the chemicals, which, by reason of their liberal use, amounts to a considerable sum, makes the treatment of slimes quite expensive, probably not less than $12 per ton.

The supply of slimes is obtained by purchase from the neighboring crushing mills, their value being previously determined by assay. This value varies from $25 to $50 per ton, and the purchase price, for some time past, has been from $3 to $5 or more per ton, according to their contents. It is said that the method of working just described extracts upward of sixty, and frequently eighty, per cent. of the assay value.

In Mr. Parke's mill, in the same neighborhood, the method of operation is very similar to that just described. He uses, however, large wooden pans or tubs, having cast-iron bottoms but wooden sides. The tubs have large capacity. The wooden sides of the tub, which are 3 inches thick, are furnished on the inside with a lining, also of wood, 1 inch thick, which, when worn down, may be replaced by new pieces without reconstructing the tub. In addition to this inner lining it has been found advantageous to attach strips of wood, 2 by 4 inches thick, to the inner circumference of the tub; these strips stand vertically, and about 2 inches apart, producing a rough or corru-

gated instead of a smooth surface on the inside of the tub. This has been found to assist greatly in the disintegration of the lumps of slime, which, although consisting of the most minute particles, hold together, like clay, with great tenacity when wet, and, in ordinary pans, frequently present a serious obstacle to thorough amalgamation. According to late advices from Virginia City, Mr. Parke has carried this improvement still further by making this corrugated surface on a rim of cast iron. The corrugations may be on the rim which is cast on the pan-bottom for the purpose of attaching the wooden staves of the side, or the rim may be cast separately and placed in the pan. The corrugated surface is 10 inches high and the rim is 3 inches thick. As the wear of a pan-rim is confined chiefly to within 10 inches of the bottom, the provision of this surface, which, like the shoes and dies, may be easily renewed when worn down, without changing the pan, is deemed a great improvement.

Roasting of Slimes.—Before the working of slimes raw, or without roasting, had been brought to the degree of efficiency that it has in the hands of the Messrs. Janin, some efforts were made to devise cheap methods of roasting them with salt at a cost that would leave some margin of profit. The usual means of roasting first-class ores is by reverberatory furnaces, which involve a large expense, especially in labor, as the material to be roasted must be constantly stirred and turned, in order to present every particle to the oxidizing and chloridizing agencies. The cost of this method is too great for slimes of ordinary value.

For the purpose of effecting a cheaper roasting, a furnace was devised, some time since, the chief object of which is to accomplish the operation with the least possible amount of manual labor, using some mechanical contrivances for stirring the pulp, and partly effecting, by the same means, the continuous supply and discharge of the material. This invention, known as the O'Hara and Thompson Roasting Furnace, sometimes as the Yerrington Furnace, from the name of the proprieter of the patent, consists of a horizontal flue 4 feet wide and 11 inches high in the arch and 80 feet long, built of common brick. At the two sides are three fireplaces, one near the middle on one side, two near the ends on the opposite side. At one end of the furnace is a chimney, but the main flue, just described, instead of opening directly into it,

is connected with it by two side flues, that branch off from the main flue about ten feet from the stack, leaving space for a platform between the stack and the end of the main flue, which is open, or only closed by a sheet-iron door. The firing being in progress in the several fireplaces, the heat passes along the main flue and then by the branch flues to the stack. The material to be roasted is put on the platform at the end of the flue near the stack, and is moved, by the mechanical appliances referred to, into the flue and slowly along its whole length, at such speed as may be desired, and, at the same time, subjected to constant stirring and turning. This is effected by means of an endless chain, passing through the flue, and carrying a number of scrapers, which, as they move along the flue, just rest on the bottom. The chain moves over two pulleys, one at each end of the flue, and is so arranged as to pass, in one direction, in and through the flue, and, in the opposite direction, outside of and above it. At two opposite parts of the chain are two circular pieces of iron, having the form of a ring, with a diameter about equal to the width of the flue. To each of these circles are attached the scrapers, six or eight in number. They are shaped something like a plowshare. As they pass through the stuff spread on the flue bottom they move it along and turn the particles with which they come in contact. The scrapers may be so set on the ring that the entire surface of the flue bottom is covered at some time by one or another of them. According to the angle which the face of the scraper makes with the larger axis of the flue the forward movement of the material will be greater or less. By this means, as well as by the speed at which the chain is caused to move, the length of time which a given portion of the material shall occupy in passing through the flue may be determined. The rings, carrying the scrapers, are jointed or hinged so as to pass over the pulleys on which the chain moves. At each end of the flue is a sheet-iron door, the lower part of which is hinged so that the rings may pass. There are also slots cut in the hinged parts for the passage of the chain.

This furnace, although devised several years since and affording then satisfactory results with experimental trials, has not yet come into general use. Some furnaces of this kind, but differing in some details of construction, were

built, in 1868, at the Rising Star mine, in Idaho, but, owing to the stopping of the mine, were not long in operation.

In the first furnace of the kind, built at the Merrimac mill, on the Carson River, experiments, on a large scale, showed that slimes could be roasted at a cost varying from $5 to $7 50 per ton, according to the price of fuel, and chloridized to such a degree that from seventy-five to eighty per cent. of the assay value could be extracted, after the roasting, by working in pans. The treatment of the roasted material, in pans, should not cost more than $4 or $5 per ton.

Another furnace, known as the "Stetefeldt," designed for the cheaper roasting and chloridizing of ores, will be described further on.

Concentration of Tailings.—Tailings, in the Washoe district, have generally been found more profitable than slimes. It has been already said that the stream of water, carrying the tailings out of the mill, is usually passed over blanket-tables, in order to save all that can possibly be obtained in that way.

The blanket-table, the most common means of concentration, is a long shallow trough, about 20 inches wide, with sides only an inch or two high, and of indefinite length, according to the supply of tailings, water, the character of the ground, and other conditions. A number of these tables are usually established side by side, sometimes only two, three, or four together, sometimes as many as fifteen or twenty. They are inclined gently, usually having a fall of six or twelve inches in twelve feet of length. They are covered with coarse blankets, made especially for the purpose, in strips about two feet wide, and cut in such lengths, usually ten or fifteen feet, as may be deemed convenient for removal and washing. As the stream of tailings runs over the blankets the heavier portions of the ore, sulphurets, &c., and particles of amalgam, are retained in the blankets, while the poorer sand is washed away. The quantity of water must be carefully adapted to the purpose, sufficient to prevent the accumulation of sand and not enough to carry away the heavier particles. The operation is usually assisted by a man who, with a broom, sweeps the surface of the table lightly, aiding the even distribution of the material and exposing the particles more thoroughly to the action of the

water. The blankets are taken up from time to time and washed out in a tub of water, usually once in twelve hours. While the blankets of one table are being washed the stream is turned so as to run over the neighboring tables. The concentrations washed from the blankets are collected and worked in pans. They usually yield from \$18 or \$20 to \$30 per ton.

In each of the principal cañons or ravines in which the mills are situated, below Virginia City, are continuous series of blanket-tables, making in the aggregate several miles. Some of the tables are owned by mills, discharging tailings into the cañon, but generally they belong to other parties, who agree with the mill-owner for the use of the tailings. According to the report of the Surveyor General, Mr. Marlette, there were in 1866 over 2,200 feet of blanket-sluices in Six-Mile Cañon. Their cost is estimated at about \$1 per foot, including blankets.

At the Santiago mill, on the Carson River, there are sixteen tables, side by side, 100 feet long. They belong to the mill, which crushes 50 tons of ore daily. The tailings pass over the tables, yielding about five tons daily of concentrations, which produce about \$20 per ton. Two men are necessary to attend to them. Of the sixteen tables eight were designed for use in the night, leaving the blankets to be washed in the day-time when the stream passed over the other eight; but when the washing is performed day and night, eight tables are sufficient for the quantity of ore above mentioned. At the Brunswick mill, also on the Carson, the amount of ore crushed, and the quantity and value of the concentrations were in about the same proportions as above given. The profit accruing from this source to the mill reduces considerably the original cost of crushing and amalgamating.

The following are the results of working some concentrated tailings, from the Atchison mill. The assays, on which the original value of the tailings is predicated, were made of samples selected from the heap. In the several months included in the report, the proportion of the number of assays to the number of tons worked was not always the same. In the best lot there was one assay for about 10 or 12 tons of the concentrated tailings.

| | November, 1866. | | | December, 1866. | | | January, 1867. | | |
|---|---|---|---|---|---|---|---|---|---|
| Tons worked | 120 | | | 148 | | | 314 | | |
| | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. |
| Assay value per ton | $11 85 | $49 59 | $61 44 | $12 73 | $53 92 | $66 65 | $10 54 | $42 77 | $53 31 |
| Yield per ton | 6 40 | 23 12 | 29 52 | 5 75 | 19 59 | 25 34 | 4 36 | 12 88 | 17 24 |
| Proportion of gold and silver—in assay value of tailings. | 19.3 | 80.7 | 100.0 | 19.1 | 80.9 | 100.0 | 20.0 | 80.0 | 100.0 |
| Proportion of gold and silver in bullion. | 21.7 | 78.3 | 100.0 | 22.7 | 77.3 | 100.0 | 25.3 | 74.7 | 100.0 |
| Percentage of gold and silver extracted. | 54.0 | 46.6 | . . | 45.2 | 36.3 | . . | 41.3 | 30.1 | |
| Yield per cent. of assay value | 48 | | | 38 | | | 32.4 | | |

Various other contrivances for concentration have been introduced into the district, but none, so far, have come into general use.

Among other noticeable machines for this purpose is Hunter's concentrator, which has been used for several years in California, and which the inventor sought, about a year ago, to apply successfully to Comstock tailings This is a percussion table of small size, being about 30 inches long by 24 wide, so suspended in a frame-work as to admit any desired inclination and the slight movement imparted by the percussion. The bottom of the table is slightly inclined from each end toward the middle. The tailing end is usually placed about an inch lower than the head. The material is supplied by a distributing launder about 8 inches from the head and, close by it, nearer the head, is a launder supplying clean water, which, like the material to be concentrated, is fed through a series of holes, so as to distribute it evenly across the table. The percussion is applied at the lower end of the table, at the rate of 200 to 240 shocks per minute. Its effect is such that the denser particles are sent toward the head in resistance to the stream of water, while the lighter particles yield to the force of the water and are carried down to the lower end and discharged. The separation therefore takes place at the point of supply, the heavier particles moving in one direction and being discharged at the head, the lighter sand moving with the water to the lower end and discharging there. A revolving scraper, just touching the sur-

face of the material, assists the discharge of the waste-sand after its separation from the heavier portion. The inclination given to the table, the speed of the percussion movement, and the quantity of water used, determine the degree of concentration. The capacity of the table is stated at 2 or 2½ tons in 24 hours. Very little power is required and one man can attend to many tables.

Tailing Reservoirs.—The tailings coming down the cañons from the mills above, after having passed over the blanket-tables, or having been subjected to other methods of concentration, are finally allowed to accumulate in reservoirs. Some of these, of small capacity, are placed along the course of the streams, but the principal deposits of that sort are on the level land adjacent to the mouths of the cañons. Thus at Dayton, where Gold Hill Cañon opens upon the plain, there are two or three reservoirs, the aggregate contents of which probably amount, at present, to 400,000 tons. This quantity is daily increased by what is brought down by the stream from mills above. Further down the river, near the mouth of Six-Mile Cañon, and receiving everything brought down from the mills on that water-course, is another known as the Carson reservoir, containing not less than 200,000 tons of tailings. In Six-Mile Cañon, two miles above its mouth, is a smaller reservoir, formerly estimated to contain 100,000 tons, but of which a large portion was swept away, some time since, by freshets. The quality of the tailings in these dams varies considerably, depending on several conditions, among others, the proportion of slimes that may be mixed with the sands. Thus assays of the slimy and richer parts may show a value of $25 or $30 per ton, while the coarse sands vary in value from $4 or$5 to $12 or $15 per ton, according to the original character of the ore and the degree of efficiency with which its valuable contents have been extracted.

The contents of some of the smaller reservoirs about Dayton are said to have an average value of $16 to $18 per ton, though the larger reservoirs are probably less rich, a number of assays giving results varying from $9 to $13 per ton. The Carson reservoir has been tested by many assays, varying between $7 50 and $25, averaging about $13 per ton.

Amalgamation of Raw Tailings.—There are now a number of estab-

lishments in the district engaged entirely in working over the tailings of the crushing mills. Some of the smaller ones are situated in the cañons or in the immediate vicinity of the mills which furnish their supply, but the most important are placed near the large reservoirs just described and draw from them the material for their work. The largest of all the mills thus engaged is that of Mr. Birdsall, at Dayton. This mill was formerly a crushing mill, provided with 30 stamps and 20 Wheeler pans. It has lately been refitted and devoted to the working of tailings. The stamps, of course, are useless for this purpose. A number of large Horn pans have been added to the machinery of the mill, making 30 or 35 pans in all, with capacity for working between 250 and 300 tons of tailings per day. The mill has an excellent water-power, derived from the Carson River, ample for all its needs. As it is conveniently placed with reference to the supply of material, it should be able to do its work very economically. It is said that the business of this mill is exceedingly profitable, but the writer is not in possession of definite information concerning the yield of the tailings or the costs of working them.

In the neighborhood of the Birdsall mill, also at Dayton, and engaged in working tailings from one or more of the reservoirs there, is the mill of Messrs. Janin and Baldwin. This mill has five McCone pans, with a capacity of about 50 tons per day. It is driven by steam, an engine of 12-inch cylinder doing the required work. Each pan works a charge of 4,000 or 5,000 pounds; and four or five charges per day, making a full duty of 10 tons per pan for each 24 hours.

Sulphate of copper and salt are supplied to the pans with each charge; the former reagent in quantities varying from 3 to 6 pounds per ton of tailings, and the latter largely in excess, from 20 to 30 pounds per ton. The pans are covered, and supplied with steam, keeping up a high temperature. The yield obtained is thought to be about sixty per cent. of the assay value, which is said to average \$16 or \$18 per ton. From the accounts of this mill, furnished by the kindness of Mr. Baldwin, it appears that during five months, ending October 31, 1869, the quantity worked was 6,732 tons; of which the average yield was \$9 75 per ton. The total expense of the mill during these

five months, covering not only the costs of working, but both ordinary and extraordinary repairs, amounted to $43,672 79, or $6 48 per ton. The mill, however, was refitted during this time and several new pans were purchased to replace others that were worn out. The current costs of operation appear, from the accounts of these five months referred to, to be about as follows:

| | Per ton. |
|---|---|
| For labor | $1 40 |
| Quicksilver, lost | 95 |
| Salt | 68 |
| Sulphate of copper | 65 |
| Fuel | 1 20 |
| Castings | 12 |
| | 5 00 |

To this may be added some incidental expenses, not very large under ordinary circumstances. In the month of October, when the mill worked 1,556 tons, the whole expense per ton was $5 60. The tailings worked in this mill are rather richer than the average material of taht sort, and are therefore treated with a larger quantity of chemical reagents, making for these items a large cost. Wood is also expensive in the neighborhood of this mill, costing not less than $10 per cord, and often more. Tailings of lower grade, requiring less outlay for chemicals, worked in less time, especially if in mills of greater capacity, may be treated for proportionately less money. In Avery's tailing mills, in Washoe Valley, where wood is obtained at $6 per cord, the cost pe- ton is said to be $3 50. In Janin & Baldwin's mill there are seventeen men employed, comprising one foreman, five amalgamators, (three by day and two by night,) two engineers, one wood-passer, three teamsters, (bringing tailings from the reservoir,) and five shovelers, (loading teams and turning the tailings over to dry.)

## SECTION V.

### TREATMENT OF FIRST-CLASS ORE.

The treatment of the first-class ores was briefly referred to in the first part of this chapter. The combinations in which the gold and silver exist in these unfit them for profitable treatment in the simple grinding and amalgamating process which has been described in the foregoing pages. They require a chloridizing roasting, after which they are amalgamated in barrels. The quantity of high-grade ore now produced in the district is so small that the single establishment of Mr. J. H. Dall, in Washoe Valley, has much more than sufficient capacity for its treatment.

It has already been shown that during the twelve months ending July 1, 1868, the Savage mine, which was then the chief source of high-grade ore, produced but 277½ tons of so-called first-class ore; and in the following year only 68¾ tons. The establishment referred to, which is built in connection with a wet-crushing and pan-amalgamating mill, has twenty stamps for dry crushing, eight reverberatory roasting furnaces, and twelve barrels, capable of treating some three or four hundred tons per month.

The method of treatment to which the ore is subjected consists of drying, crushing by stamps without the use of water, roasting with salt, amalgamation in revolving barrels, and the separation of the gold and silver from the quicksilver by the usual method of retorting. These principal features of the process will be briefly described.

Drying.—The drying kiln consists of a series of flues, covered by a cast-iron floor, on which the ore, already reduced to a size suitable for stamping, is spread. The surface for the reception of the ore is about 8 feet wide by 12 feet long. The iron is cast in sections or plates, 8 feet long by 3 feet wide, with a strengthening rib on the under side. The base of the kiln is brickwork, and the flues are about 8 inches deep. They are covered by the iron plates. At one end of the kiln is a fireplace, and at the other a stack, so that the heat passes from one end to the other under the iron cover or floor, on which the ore is spread to a depth of 4 or 5 inches. The ore is constantly raked and turned until quite dry.

When the kiln is conveniently placed, as in some similar establishments

in Eastern Nevada, the heat from the roasting furnaces, on its way to the stack, passes through the flues, saving a special firing. In the present instance there are three kilns, able to dry about twenty-five tons per day, consuming in all about a half cord of wood in twenty-four hours, and requiring one man's attention to keep up fires and rake over the ore.

Crushing.—For crushing the rock, after drying, there are twenty stamps, arranged in batteries of four, weighing about 600 pounds each, dropping 8 or 9 inches about 65 times per minute. The foundations and battery-frame are not essentially different from those in wet-crushing batteries. The mortars differ from the high ones used for wet-crushing, consisting of a bed-piece with sides and ends that are only high enough to provide the means of bolting the iron casting to the wood-work of the battery-frame, attaching the screen-frames, &c.

The dies are flat, circular pieces of cast iron, that fit into recesses in the bottom of the mortar. Each die has two lugs or projections on its periphery, which, being dropped into a groove in the bottom of the mortar, may then be revolved 90 degrees, under a flange or lip with which the recess is cast. Molten lead is then poured in to hold the dies firmly. When it is desired to remove them, quicksilver is poured into the battery, dissolving the lead and loosening the dies. By retorting the quicksilver, both metals are recovered.

The discharge is at both sides and ends. Screens of brass wire-cloth are used, having 40 meshes to the lineal inch, or 1,600 holes to the square inch. The stamps crush from a half ton to one ton per head per day of twenty-four hours. The batteries are inclosed by housings or closely fitted boxes, which serve as receivers for the crushed material. The casings are provided with doors, by means of which the workmen can enter and remove the crushed ore by shovelling it into barrows.

Roasting.—The fine ore is then roasted with salt in reverberatory furnaces. These are built of common red brick. Figs. 1 and 2, on Plate XXIV, show the method of their construction.[1] Fig. 1 is a horizontal section through the line, *A B*, on Fig. 2. In the drawings, *H* is the hearth; *D*, the

[1] From drawings furnished by Mr. J. B. Hiskey.

stirring door; *d*, the discharge door; *G*, the grate; *C*, the bridge; *F*, the flues; *P*, the ashpit; *J*, the hopper. The charge consists of 1,000 pounds of ore, which is mixed with six per cent. of salt, the latter being added to the charge in the hopper by which the furnace is supplied. The charge is heated very gently at first, the temperature being gradually raised, until at the end it is subjected to a high heat. Usually six hours are required for the roasting. The charge is constantly stirred, and once or twice during the operation it is turned; that is, the portion of the charge remote from the bridge is caused to exchange place with that which is near.

The operation effected by thus roasting with salt consists, very briefly expressed, first, in the oxidation of the metallic compounds, converting the sulphurets, in which form the silver chiefly exists in the ore, to sulphates; and the subsequent decomposition of these combinations by the salt, with the formation of the chlorides of the metals. Sometimes an addition of limestone is made to the charge, for the purpose of decomposing the chlorides of copper, zinc, &c., thus preventing, to some extent, their subsequent amalgamation in the barrel, and obtaining bullion of a purer quality.

Each furnace, roasting four charges of 1,000 pounds each, or two tons, in twenty-four hours, consumes one cord of wood. Two stirrers are employed on each twelve-hour shift, making four men in twenty-four hours. One man is required to receive and attend to the ore on the cooling floor, after its discharge. The same man can attend to more than one furnace.

The roasted ore is passed again through a screen, having 1,600 holes to the square inch, in order to remove from it any lumps that may have formed by caking in the furnace, or coarse particles that may have escaped the battery-screen. It is then elevated to a large hopper, placed above the amalgamating barrels, to which latter it is thence supplied by means of smaller hoppers, one of which is suspended over each barrel.

BARREL AMALGAMATION.—The barrels are 4 or 5 feet in length and diameter. They are usually made of soft pine. Figs. 3 and 4, on Plate XXIV, show a vertical section and end view of an amalgamating barrel, formerly used at the Gould and Curry mill. The ends of the barrel are made of plank, nicely fitted together and joined with a tongue of hard wood. The

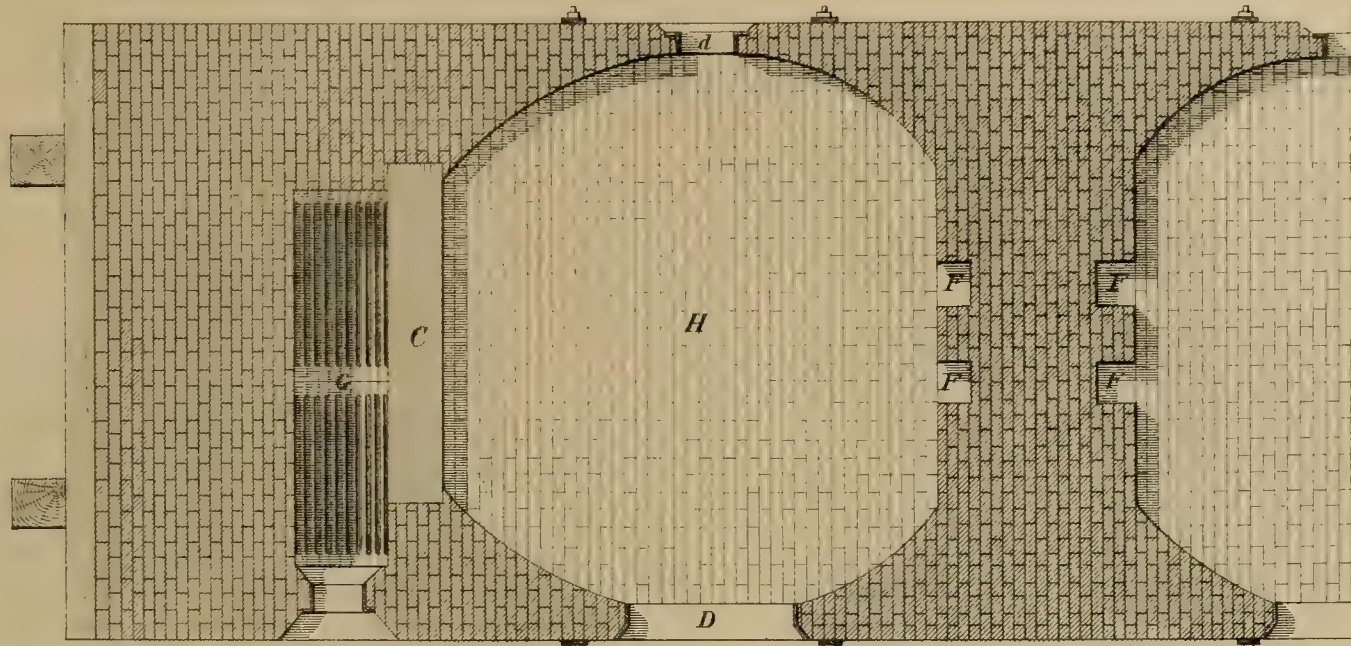


*Fig. 1.*

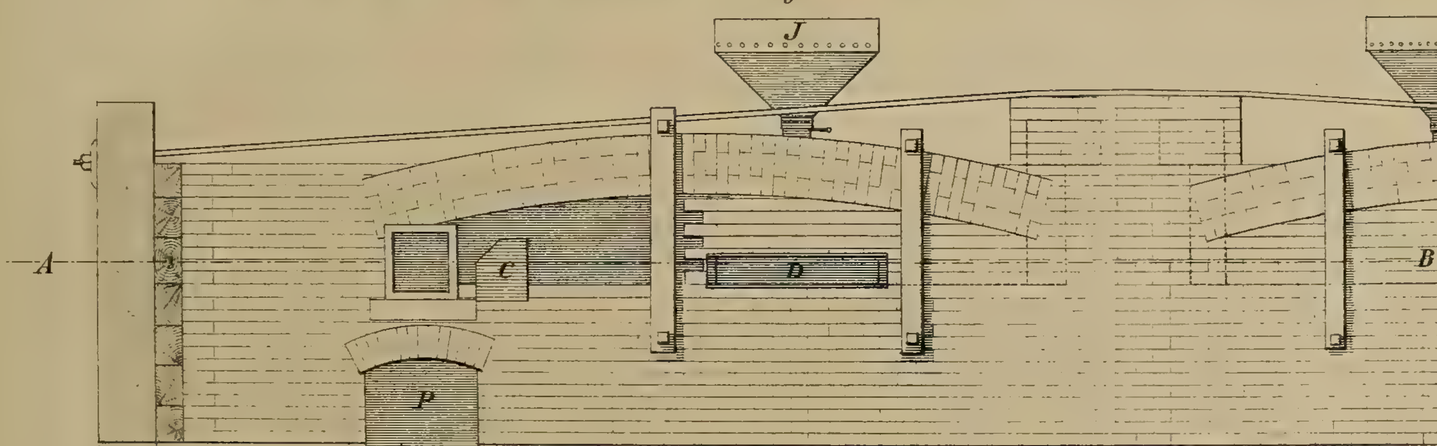


*Fig. 2.*

Scale: $\frac{1}{48}$.

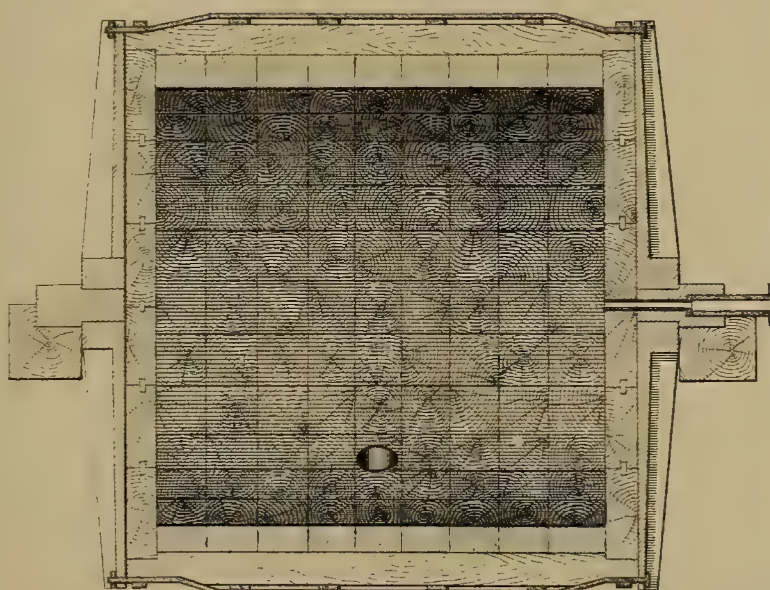

*Fig. 3.*

Scale: $\frac{1}{24}$.

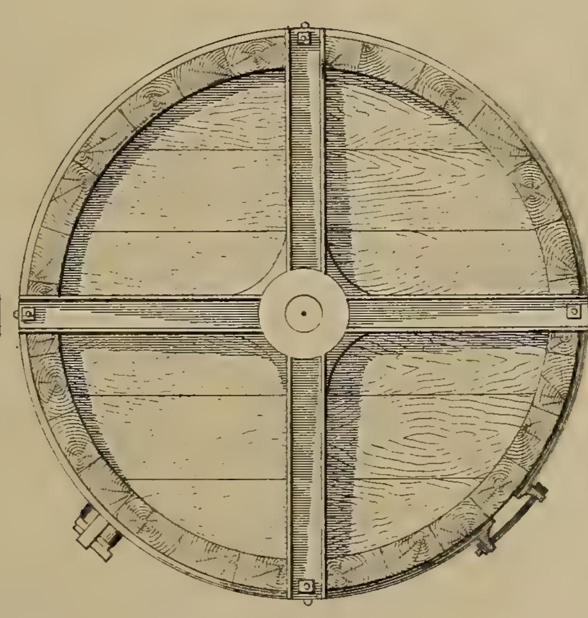

*Fig. 4.*

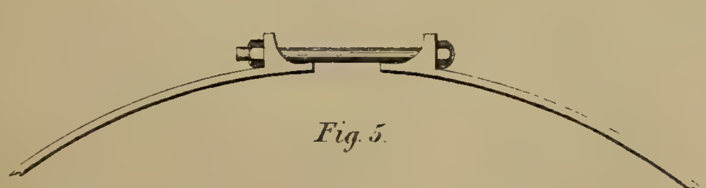

*Fig. 5.*


*Fig. 6.*

Scale: $\frac{1}{12}$

staves of the barrels are sometimes made of six-inch stuff, without lining; sometimes, as shown in the figure, the staves are 2 or 3 inches thick, with an interior lining of blocks 4 or 5 inches square, and 3 or 4 inches thick, and so placed in the barrel that the wear is on the end of the grain. This lining can be removed when worn out. The staves of the barrels are bound with iron hoops, the ends of which are drawn together as shown in Fig. 5. The ends of the barrel are strengthened by a four-armed flange of cast iron. The barrels are caused to revolve by cog-gearing, the teeth being put on in segments, around the end of the barrel; or by belting, or, as at Austin, by friction-gear. The barrel, of which a section is shown in Fig. 3, shows a contrivance for admitting steam to the pulp through the trunnion. This arrangement, not very common, consists of a steam-pipe, *p*, Fig. 6, which enters the trunnion and fits smoothly against the end of another pipe, *q*, that passes through the end of the barrel and admits the steam to the interior. The interior pipe, *q*, revolves with the trunnion, while the exterior pipe, *p*, is fixed and remains without motion. The trunnion, *T*, is keyed to the flange already referred to.

The barrels are charged with about 2,000 pounds of ore, mixed with water enough to make a moderately thick paste. Before adding quicksilver, the charge is revolved for two or three hours in the barrel with several hundred pounds of scrap-iron. The object of this is to effect a partial reduction of the chlorides present, which would otherwise be performed at the expense of the quicksilver. The chloride of silver is partly reduced by the metallic iron, and is subsequently amalgamated by the quicksilver. The same is true of the lead and copper. Quicksilver is added according to the richness of the ore, usually varying from 250 to 500 or more pounds. The barrel is run two hours, at twelve or fifteen revolutions per minute, and then examined that the consistency of the paste may be ascertained. If the latter is too thin, the quicksilver settles on the bottom. This condition is remedied by the addition of more roasted ore; while if too thick for the most favorable distribution of the quicksilver, more water is added. The barrel is then allowed to revolve again for fourteen hours, making fifteen revolutions per minute. The whole time occupied from the charging to the discharging of the barrel is eighteen or twenty hours. When the amalgamation is complete, the paste is thinned by

the addition of water, and the quicksilver and amalgam are thus allowed to collect on the bottom of the barrel.

Below the barrels is a large hopper or funnel-shaped contrivance, sloping down from the four sides to a common center. When a barrel is to be discharged, a small plug in the side is loosened while turned upward, and when the barrel is revolved, so that the plug is downward, it is drawn out by hand. The quicksilver and amalgam are discharged into the hopper or funnel just described, and are allowed to run from the barrel until the pulp begins to follow, when the plug is replaced. When all the barrels, ready for that purpose, are discharged, the amalgam in the hopper is carefully collected and washed, and afterward cleaned in a common pan like those in use in other mills for similar purposes. The straining of the quicksilver and retorting of the amalgam is performed in manner similar to that already described.

After the hopper below the barrels has been cleaned of all the quicksilver discharged into it, the residue is permitted to flow from the barrels and to run down into a large agitator, eight or ten feet deep, and twelve or fifteen feet in diameter, in which stirring-arms are revolving in manner similar to that already described in the foregoing. By this means, the unseparated quicksilver and amalgam are allowed to settle, and the concentrations of this vessel are worked over in pans in the common way, while the mass of tailings, passing from the settler, are subjected to further methods of concentration and subsequent treatment.

The actual costs, in detail, of the treatment of ore by this method, or the actual percentage of value obtained from the ore, are not definitely known to the writer. The former probably vary between $20 and $30 per ton, according to the richness of the ore, the amount of salt, quicksilver, and other material consumed, and other conditions.[1] The only mill now employed in the reduction of high-grade ores produced by the Comstock charges the producer $40 or $45 per ton for treatment and guarantees the return of eighty per cent. of the assay value of the ore. The supply of ore is so limited, and the establishment consequently unoccupied for such a proportion of the time,

[1] Wood costs, per cord, $5; common labor, per day, $3; salt, per pound, 3 cents; quicksilver, per pound, 65 cents.

that the actual costs are probably considerably greater than they would be if the mill were constantly working up to its full capacity. In effect, the mill purchases the ore of the mine for eighty per cent. of its value, less $40 or $45 per ton, the stipulated price for working, making its return in cash or bullion without any statement of the yield actually obtained.

The following is a statement concerning the first-class ore produced by the Savage mine during the year ending July 1, 1868, and treated at this mill:

| | | Tons. |
|---|---|---|
| Quantity of ore delivered from the mine | | $277\frac{1050}{2000}$ |
| Less moisture, amounting to $6\frac{9}{10}$ per cent., leaving | | $258\frac{500}{2000}$ |
| Assay value of the ore, per ton—gold | $123 66 | |
| Assay value of the ore, per ton—silver | 325 74 | |
| | | $449 40 |
| Proportion of gold in the ore, per cent. | | $27\frac{8}{10}$ |
| Proportion of silver in the ore, per cent. | | $72\frac{2}{10}$ |
| Total assay value—gold | $34, 317 08 | |
| Total assay value—silver | 90, 402 43 | |
| | | $124, 719 51 |
| Return of bullion, equal to 80 per cent. | | 99, 775 59 |
| Or per ton | | 359 52 |
| Price paid for working, per ton | | 41 87 |

*Similar statement for year ending July* 1, 1869.

| | | Tons. |
|---|---|---|
| Quantity of ore delivered from the mine | | $68\frac{420}{2000}$ |
| Less moisture, amounting to $5\frac{6}{10}$ per cent. | | $64\frac{750}{2000}$ |
| Assay value of the ore, per ton—gold | $73 69 | |
| Assay value of the ore, per ton—silver | 201 78 | |
| | | $275 47 |
| Proportion in the ore of gold, per cent. | | 26. 7 |
| Proportion in the ore of silver, per cent. | | 73. 3 |
| Total assay value of the ore—gold | $5, 026 36 | |
| Total assay value of the ore—silver | 13, 763 72 | |
| | | $18, 790 08 |
| Return of bullion, equal to 80 per cent. | | 15, 028 33 |
| Or per ton | | 220 32 |
| Price paid for working, per ton | | 43 12 |

STETEFELDT'S FURNACE.—The most expensive item in the cost of working first-class ores by the method just described is the roasting and chloridizing operation. This alone is generally estimated at $15 per ton of ore, though it is sometimes less. Any efficient method of obtaining the same results at a less cost is greatly to be desired, since there are many mining districts, not only in Nevada, but throughout our silver-producing regions, the development of which is hindered by the want of cheaper metallurgical processes.

Within the past year a new furnace, devised and introduced by Mr. C. A. Stetefeldt, of Austin, has been put in operation near Virginia, and, judging by the experience thus far obtained, it promises results that will be of great importance to our silver mining districts. It is reported that one of these furnaces is about to be built for the Manhattan Company, in Austin, a region where, as will be shown further on, cheap roasting is very much to be desired. A brief description of the Stetefeldt furnace is given in the following paragraphs.

This is designed as a desulphurizing and chloridizing furnace. Its operation consists essentially in allowing the very finely pulverized ore, mixed with salt, to fall against a current of hot air that rises in a shaft, during which fall the fine particles of sulphureted metals are decomposed, forming metallic oxides, sulphurous and sulphuric acid. The latter attacking the salt, chlorine is liberated, which combines with the oxides of the metals, or acts upon the still undecomposed particles of sulphuret, thus producing the metallic chlorides.

The chemical action is in most respects the same as that which takes place in the reverberatory roasting furnace, but as the ore falls in a finely divided condition, or shower of particles, each atom is exposed more freely to the operation of the heat and the oxidizing and chloridizing agents; their effect is more rapid and complete while the amount of manual labor required is very much less than in the reverberatory. The furnace was invented several years since and an experimental one was built at the mine of the Twin River Company, in Ophir Cañon, Nevada; but although affording results that were in most respects satisfactory, it was not then brought into continued use. During the past year another, designed for regular and permanent operation, was built at Reno, near Virginia, and employed in roasting ores brought from

Humboldt County. This furnace consists of a shaft something over 20 feet high and from 3 to 4 feet square. At the base of the shaft, on two opposite sides, are fire-places from each of which a short flue leads to the main shaft. At the top of the shaft is the feeding machinery, which supplies the finely pulverized ore in a continuous stream. Just below the top of the shaft is a flue through which the gases escape, and leading from the furnace to a series of dust chambers, in which the heated current may deposit that portion of the fine material which it carried upward with it. An auxiliary fireplace in this flue serves to sustain the heat and prolong the oxidizing and chloridizing operation. A discharge door is at the bottom of the main shaft, whence the bulk of the material that has been acted upon is withdrawn; and similar doors are placed at convenient points along the main flue and in the dust chambers. The main stack, for the final escape of the gases, is at the end of the dust chambers and is about 40 feet high.

In the regular operation of the furnace the ore is mixed with salt on the drying floor and then crushed under stamps. The screens used in the crushing battery are No. 40. It is then raised by an elevator to the top of the furnace and deposited in the hopper of the feeding machine, whence it is supplied continuously to the furnace. The heat in the shaft is maintained as uniformly as possible, and at a sufficiently high degree to keep the ore, which accumulates at the bottom, red hot. From time to time this ore is discharged through the doors at the base of the shaft and in the flue, or canal, leading to the dust chamber.

It is claimed by Mr. Stetefeldt, as a result of actual experience at Reno, that this furnace performs a more efficient chloridizing roasting, with far less cost for labor, fuel, and salt than is the case with the reverberatory furnaces. It is said that about ninety per cent. of the silver contained in the ore is chloridized. One Stetefeldt furnace, operated by 8 men, accomplishes the treatment of 20 tons of ore, which would require 10 reverberatory furnaces and the labor of 36 men. The fuel thus far used in the furnace at Reno averages about two cords per day, and may roast at that rate of consumption the same quantity of ore which would require the consumption of ten cords in a reverbatory furnace. The salt used in the Stetefeldt furnace varies from three to six per cent., according to the richness of the ore, while in the reverbera-

tory furnaces about twice that quantity is expended; the principal cause of difference being that in the shaft-furnace the salt is more thoroughly utilized, every particle accomplishing its purpose.

It is also claimed by Mr. Stetefeldt that the bullion produced from ore roasted in this furnace is of a higher quality than where the reverberatory is employed, owing to the decomposition of the chlorides of the base metals. These chlorides are formed in the shaft-furnace but are again decomposed in the presence of steam derived from the burning fuel, thus forming hydrochloric acid and the oxides of the metals. The roasted pulp accordingly contains much less of the chloridized base metal than it would if the ore were roasted in a reverberatory. In this respect it is held that the furnace is admirably adapted to the treatment of base ores.

The cost of roasting per ton, thus far, at Reno, is said by Mr. Stetefeldt to be between $6 and $7, which may be reduced by projected improvements and by working the furnace at full capacity.

# CHAPTER V.

## CHEMISTRY OF THE WASHOE PROCESS.

BY ARNOLD HAGUE.

Mineralogical character of the ore—Chemical action of mercury and other reagents—Pan experiments—Chemistry of the process.

The adaptation of the amalgamation process to the reduction of argentiferous ores depends to such an extent upon their character that in considering its application to Washoe it is necessary, as far as possible, to understand the true nature of the varied mineral ingredients that constitute the ore of the Comstock vein.

A large number of mineral species have been found in the vein during the course of its development; very many of them, however, are extremely rare, while others only have been observed near the surface, or within very limited areas.

A discussion of its mineralogical features will be found in another chapter; it is only desirable here to consider such minerals as are everywhere scattered through the body of quartz, and are present in sufficient quantities to materially affect the question of the amalgamation of the associated gold and silver. The average ore as it comes from the mines presents to the eye a mass of nearly white, brittle, crumbling quartz, ranging in size from fine dust to pieces that weigh several pounds; occurring with it are small fragments of wall-rock and clay, that impart a somewhat grayish tinge. An inspection of the ore piles at the different mines and mills generally shows the presence of iron and copper pyrites. Except in first-class ore, which is always roasted before being sent to the amalgamating pan, it requires a somewhat closer examination to detect well-defined specimens of other minerals, so finely are they disseminated through the entire mass. A more careful search, however, will generally de-

velop the presence of blende, galena, and argentite; more rarely, polybasite and stephanite.

Samples of finely crushed ores were subjected to a microscopical examination. The following minerals were observed: quartz, small cubes and particles of iron and copper pyrites, flakes of blende, and thin pieces of a dark lead-gray mineral, which were determined to be argentite.

In order to determine the chemical and mineralogical composition of the ore more accurately, samples of carefully chosen first and third-class rock were subjected to a thorough analysis. The first-class came from the Savage mine, and was taken from a lot of ore that had been crushed at Dall's mill. Its assay value was $489 22. The third-class ore came from the Kentuck mine; it was obtained at the mill from the troughs immediately after leaving the batteries, in the same manner as the mill samples are ordinarily taken. The material used was selected from 300 or 400 pounds of crushed rock, collected at intervals during a day's run of twenty-four hours. Its assay value was $43 74.

The results of both analyses were as follows: No. 1, Savage ore;[1] No. 2, Kentuck ore:

| | No. 1. | No. 2. |
|---|---|---|
| Silica | 83.95 | 91.49 |
| Alumina | 1.25 | 1.13 |
| Protoxide of iron | 1.95 | .83 |
| Protoxide of manganese | .64 | |
| Lime | .85 | 1.42 |
| Magnesia | 2.82 | 1.37 |
| Potash and soda | 1.28 | 1.05 |
| Sulphide of zinc | 1.75 | .13 |
| Sulphide of lead | .36 | .02 |
| Sulphide of silver | 1.08 | .12 |
| Subsulphide of copper | .30 | .41 |
| Gold | .02 | .0017 |
| Bisulphide of iron | 1.80 | .92 |
| Moisture | 2.33 | .59 |
| | 100.38 | 99.48 |

[1] The writer is indebted to Mr. William G. Mixter for the analysis of the sample from the Savage mine.

No arsenic or antimony was detected in either case, not even after subjecting considerable quantities to Marsh's test. It is, therefore, inferred that stephanite and polybasite were both absent. It was found impossible to separate the native silver, if any was present, from that existing as argentite; of the former none was observed, but the latter could be recognized under a glass: it is, therefore, all calculated as sulphide of silver. The sulphur obtained has been combined with the zinc as blende, with lead as galena, with silver as argentite, with copper as subsulphide, and the remainder with iron as bisulphide. The iron still remaining has been estimated as protoxide. It was found impossible to separate the metallic iron, coming from the stamps of the batteries, from the sesquioxide of iron, occurring in the rock and clay material of the vein. The substances found in both analyses are the same, with the exception of there being no manganese in the sample from the Kentuck mine, the differences being only the variable proportions of the same minerals. If in the two analyses we reject the gangue and such matter as can have no other influence upon the extraction of the precious metals than a physical one, by affecting the mechanical conditions in the grinding of the ore, or the consistency of the pulp, and consider only those ingredients that may influence the chemical conditions during the operation in the pan, we have the following:

| | No. 1. | No. 2. |
|---|---|---|
| Protoxide of iron | 1.95 | .83 |
| Bisulphide of iron | 1.80 | .92 |
| Subsulphide of copper | .30 | .41 |
| Sulphide of zinc | 1.75 | .13 |
| Sulphide of lead | .36 | .02 |
| Sulphide of silver | 1.08 | .12 |
| Gold | .02 | .0017 |
| | 7.26 | 2.4317 |

Chemical Action of Mercury and other Reagents.—The ore of the Comstock vein may be regarded as composed of the following:

Gangue, quartz.

Metal-bearing minerals of common occurrence: blende, galena, argentite, silver, gold, iron pyrites, copper pyrites.

Minerals of much more rare occurrence: stephanite, polybasite.

The following experiments were undertaken to ascertain, as far as possible, the action upon the minerals of the Comstock ores, just enumerated, of mercury, and such chemical agents as are employed in the amalgamation process, or may be formed during the operation in the pan.

Mercury and native silver, when rubbed together, unite easily.

Mercury and chloride of silver, the latter prepared in the wet way, when brought in contact, form amalgam and chloride of mercury.

Mercury and argentite: The mineral was first pulverized and mixed with a little fine sand, the metal added, and the mass allowed to stand for some time; occasionally rubbed together in a mortar. Amalgamation ensued; it was, however, imperfect, much of the mineral being unacted upon.

Mercury with stephanite and polybasite, under the same conditions as the last experiment, gave similar results; the decomposition, however, appeared to be more complete, probably owing to the more finely divided state of these minerals than the more sectile argentite.

The above experiments with native silver, chloride of silver, argentite, and polybasite, were repeated with mercury containing a small quantity of copper-amalgam in solution. In the case of the two former there was the same action as when the pure metal was used; with the two latter the decomposition was more perfect and satisfactory.

Chloride of silver, argentite, and stephanite were each subjected to the action of mercury and fine metallic iron, with a constant application of heat. The energy displayed by the mercury was much more marked than when employed separately. In the case of the chloride, the decomposition was quite rapid, and the surface of the metal remained bright and clean.

Chloride of copper and pulverized argentite were allowed to stand together for ten days, in the cold, with an occasional application of heat, at the end of which time, a small quantity of chloride of silver was formed. A trace of sulphuric acid was found in the filtrate.

Two grammes of the pulverized mineral were also treated with a moderately concentrated solution of chloride of copper placed in a bottle, with a

tightly-fitting stopper, to prevent access of air. It was exposed for twenty-four hours to a temperature of 90° centigrade. Sulphuric acid and sub-chloride of copper were found in the solution. Chloride of silver was precipitated. After removing the soluble salts, by washing, the chloride of silver was dissolved out, by digesting it with ammonia. The residue gave, by assay, .099 grammes of silver. Two grammes of the mineral produced .1705 of pure metal; showing that, under the most favorable conditions, but little over one-half of the silver was chloridized. The application of heat greatly facilitated the decomposition.

Polybasite, after being subjected to the chloride of copper solution, at the ordinary temperature of air, also yielded a small quantity of the chloridized silver.

Argentite was exposed to the same treatment, with sub-chloride of copper, as in the last experiments. In the cold, decomposition ensued after standing several days. The residue from two grammes of the mineral, subjected to the action of heat at 90° centigrade, without access of air, gave .1655 of a gramme of silver, showing that only .006 had been chloridized.

Galena, in a pulverized condition, was digested with a strong mixture of salt and sulphate of copper, and after standing three or four weeks, at the ordinary temperature, was filtered. The residue exhibited, besides the undecomposed mineral, a light green oxychloride of copper, and a large quantity of sulphate of lead incrusting the galena.

Blende was also subjected to a similar treatment. The solution was found to contain a considerable quantity of oxide of zinc, and but little copper. The residual blende was coated with the same oxychloride of copper already noted in the case of the galena.

Two grammes of the powdered mineral were placed in a flask, a solution of five grammes of salt and seven of sulphate of copper added, and exposed for two days to a temperature of 90° centigrade. After remaining three days longer in the cold the amount of oxide of zinc found to have been dissolved was .2785 of a gramme. The same experiment was repeated with the addition of one gramme of iron filings. The latter rapidly disappeared; metallic copper was precipitated, but was redissolved, probably by the chloride of copper present, the sub-chloride being produced. Later,

the iron was thrown down as a basic salt. The oxide of zinc estimated in the solution was .3250 of a gramme.

Iron and copper pyrites are but slightly altered by the copper solutions. In practical operations at the mill they are found in the tailings without showing any appreciable signs of having been attacked.

It will be observed in the above experiments that the argentiferous sulphurets were always more or less chloridized by the action of the copper salts.

In order to indicate more clearly the relative amount of decomposition produced by the two chlorides of copper, the results are here brought together as follows: Two grammes of argentite gave .1705 grammes of silver. After treating two grammes of the mineral with chloride of copper, the residue gave .099 grammes of silver; after treating two grammes of the mineral with sub-chloride, the residue gave .1653 grammes of silver: showing that in the former 58.0 per cent., and in the latter, 2.9 per cent. was chloridized. No sulphide of copper was detected in any of the residues examined; sulphuric acid, however, was found in the filtrate in several instances.

Pan Experiments.—With a view to determine, if possible, some of the problems involved in the action of mercury, common salt, and sulphate of copper, employed in the decomposition of the Comstock ores by the Washoe process, the experiments[1] described in the following pages were undertaken upon two lots of ore, whose composition was well known.

It was necessary, in order to make the investigations of any practical value, that the material should be treated in such a manner as to imitate as closely as possible the operations carried out on a large scale at the mills, and at the same time to be able to repeat precisely the same conditions as often as desired, and to know the exact results of each trial.

Of the ores used, one was a lot of first-class rock from the Savage mine, such as is ordinarily sent, on account of its high value and large amount of base metals, to Dall's Mill, for reduction by the barrel-process, as described in a

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[1] These experiments were conducted at the Sheffield Laboratory of Yale College. The assistance of Mr. Ellsworth Daggett was obtained, and to his experience in the mechanical details of milling operations, much of the credit in carrying out the work is due.

previous chapter. The second lot consisted of several hundred pounds of third-class ore from the Kentuck mine, presented, for the purposes of the work, by the Kentuck Mining Company. This low-grade ore was selected as being well adapted for pan amalgamation; easily reduced, containing but little base metal, and the rock from which it was taken yielding very favorable results at the mill. Both ores were carefully and thoroughly sampled, and passed through a fine sieve in order that they might be well mixed. Repeated assays were made until they had as uniform a composition as it was possible to obtain. After which, to prevent any settling of the heavier particles, both lots were put up in bags, in quantities of 10 and 15 pounds each; from several of these parcels assays were made, and the results found to agree. The Savage ore assayed, gold, \$134 35; silver, \$354 87; total, \$489 22 per ton. The Kentuck ore assayed, gold, \$10 85; silver, \$32 89; total, \$43 74 per ton. The results of the chemical analyses of both samples are given above.

A small amalgamating pan, such as is used in California for the purpose of experimenting upon new ores, was procured. It was made by Mr. Wheeler as a test pan, and in all its essential features was similar to thela rger ones of his manufacture, employed in milling operations. It was 18 inches in diameter, and capable of working 20 pounds at a charge. A wooden tub, 3 feet in diameter, 18 inches deep, and provided with four wooden arms, connected with and revolved by an upright shaft in the center, served to keep the pulp in constant motion, and answered all the requirements of a settler or an agitator. A room with steam power was secured and a mill upon a small scale set up, which supplied all the necessary conditions of a larger establishment.

The manner of conducting the operations was the same in every case; the ore was first placed in the pan, the muller set in motion, water added to bring the pulp to the proper consistency, and steam admitted to a chamber below. As soon as the pulp was thoroughly heated, the salt, sulphate of copper, or such other chemical agents as were employed, after being carefully weighed, were thrown in. The mercury was immediately added, in a fine condition, being strained through buckskin. Care was always taken to maintain the pulp at the proper degree of consistency, and to preserve a constant heat, which was

frequently tested by means of a thermometer plunged into the pan. A temperature of 185° Fahr. was found to act most advantageously. The pan worked well; the grinding action was perfectly satisfactory; the ore being kept in a constant and rapid circulation, and the mercury finely disseminated through the entire mass. The muller made 118 revolutions per minute.

The operation concluded, the pulp was drawn off into the settler, the pan thoroughly washed out, or "cleaned up," and every particle of amalgam removed.

An additional quantity of mercury was placed in the settler, and water poured in until it was about half full. The stirrers made 30 revolutions per minute. The pulp was withdrawn at the end of four hours. The water, and the very lightest material, was allowed to escape, but the great bulk of sand and mercury was collected together in buckets and separated by hand, to avoid all loss. In washing, the tailings were made to fall upon a slightly inclined table, or trough, so that, if by any accident, mercury went over it could be easily recovered.

The quicksilver after being washed free from sand was strained through buckskin, and the amalgam collected for retorting. The difference in weight between the mercury used in the pan and settler and that which remained at the conclusion of a charge, after adding the amount retained in the bullion, was, in most cases, scarcely appreciable. Owing to the well-known property of mercury to retain a small portion of silver in solution, which the ordinary pressure used in separating the bullion fails to recover, the precaution was taken to have it all previously primed or charged before adding it to the pan. This was accomplished by allowing the mercury and metallic silver to stand in contact for some time, and then straining off the amalgam formed.

The amalgam obtained from each experiment was weighed and put separately in small sheet-iron cups. The number of each charge being stamped plainly on the iron, several of them were then placed together, on the bottom of a small cast-iron retort, and the mercury distilled over. After the retort had cooled down the remaining bullion was taken out and accurately weighed. Careful assays of each lot were made, and always conducted with proofs, and the metals separated by nitric acid in the usual way.

From the amount and fineness of the bullion the actual value of the gold and silver obtained from each charge is determined.

For the purposes of comparison it was considered desirable to maintain, as far as practicable, the same conditions in each trial; for this reason, there is very little variety in the treatment with chemical agents, or the duration of the operations. The relative amounts of salt and sulphate of copper employed have in every case been the same; one-half the quantity by weight of the latter to that of the former.

A large excess of mercury and reagents were used in order to point out any marked differences in the results, and at the same time to obtain the greatest possible yield of the precious metals, without regard to the purity of the bullion, or the practical advantage of the method.

The results are given in the accompanying tables; they are recorded precisely as they occurred, although there are in some instances apparent errors.

*Table showing the Results of Experiments upon Kentuck ore.*

| Number. | Amount of ore. | Chemicals. | | | Time. | Weight of— | | Fineness of bullion. | | | Actual value extracted. | | | Value extracted per ton. | | | Per cent. saved. | | Yield per cent. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Salt. | Sulphate of copper. | Quick-silver. | | Amalgam. | Bullion. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | |
| | *Lbs.* | *Oz.* | *Oz.* | *Lbs.* | *Hours.* | *Gramme.* | *Gramme.* | | | | *Cents.* | *Cents.* | *Cents.* | | | | | | |
| 1 | 20 | 1 | ½ | 4 | 5 | 31.850 | 6.073 | 21.2 | 946.4 | 967.6 | 07.28 | 23.82 | 31.10 | $7 28 | $23 82 | $31 10 | 67.09 | 72.42 | 71.10 |
| 2 | 20 | 1 | ½ | 4 | 5 | 33.810 | 6.214 | 21.4 | 940.2 | 961.6 | 07.5 | 24.21 | 31.71 | 7 50 | 24 21 | 31 71 | 69.12 | 73.61 | 72 49 |
| 3 | 20 | . . | . . . . . | 6 | 5 | 23.930 | 3.648 | 31.8 | 960.6 | 992.4 | 07.73 | 14.60 | 22.33 | 7 73 | 14 60 | 22 33 | 71.24 | 44.39 | 51.05 |
| 4 | 20 | 1 | ½ | 6 | 5 | 37.200 | 6.623 | 13.2 | 966.0 | 979.2 | 05.7 | 26.55 | 32.25 | 5 70 | 26 55 | 32 25 | 52.53 | 75.3 | 73.73 |
| 5 | 15 | . . | . . . . . | 4 | 5 | 25.750 | 5.322 | 14.2 | 967.4 | 981.6 | 04.95 | 21.33 | 26.28 | 6 60 | 28 44 | 35 04 | 60.83 | 86.5 | 80.11 |
| 6 | 15 | . . | . . . . . | 4 | 5 | 26.725 | 4.908 | 24.6 | 960.6 | 985.2 | 06.88 | 19.56 | 26.44 | 9 17 | 26 08 | 35 25 | 84.57 | 79.3 | 80.59 |
| 7 | 15 | ¾ | ⅜ | 4 | 5 | 24.240 | 4.490 | 24.6 | 971.8 | 996.4 | 06.55 | 18.05 | 24.60 | 8 73 | 24 07 | 32 80 | 80.46 | 73.18 | 74.98 |
| 8 | 15 | 3 | 1½ | 4 | 5 | 39.350 | 6.811 | 22.8 | 689.4 | 712.2 | 08.48 | 19.48 | 27.96 | 11 31 | 25 97 | 37 28 | 104.3 | 78.96 | 85.23 |
| 9 | 15 | 3 | 1½ | 4 | 5 | 39.350 | 6.967 | 23.6 | 670.0 | 693.6 | 08.7 | 19.35 | 28.05 | 11 60 | 25 80 | 37 40 | 106.9 | 78.44 | 85.51 |
| 10 | 15 | . . | . . . . . | 4 | 5 | 27.500 | 5.707 | 28.2 | 968.6 | 996.8 | 09.5 | 22.92 | 32.42 | 12 67 | 30 56 | 43 23 | 116.7 | 92.92 | 98.83 |
| 11 | 15 | . . | . . . . . | 4 | 5 | 27.500 | 5.275 | 24.8 | 972.4 | 997.2 | 07.66 | 21.27 | 28.93 | 10 26 | 28 36 | 38 62 | 94.57 | 86.23 | 88.16 |
| 12 | 15 | ¾ | ⅜ | 4 | 5 | 30.500 | 5.685 | 20.2 | 973.4 | 993.6 | 06.44 | 20.70 | 27.14 | 8 58 | 27 60 | 36 18 | 79.14 | 83.92 | 82.73 |
| 13 | 15 | ¾ | ⅜ | 4 | 5 | 30.600 | 5.730 | 20.2 | 955.2 | 975.4 | 06.49 | 22.71 | 29.20 | 8 65 | 30 28 | 38 93 | 79.72 | 92.06 | 89.00 |
| 14 | 15 | 1½ | ¾ | 4 | 5 | 32.600 | 5.830 | 18.2 | 947.4 | 965.6 | 07.05 | 22.91 | 29.96 | 9 40 | 30 54 | 39 94 | 86.63 | 92.85 | 91.08 |
| 15 | 15 | 2¼ | 1⅛ | 4 | 5 | 33.400 | 5.830 | 16.6 | 887.2 | 903.8 | 06.43 | 21.45 | 27.88 | 8 56 | 28 60 | 37 16 | 78.89 | 87.26 | 84.95 |
| 16 | 15 | 3 | 1½ | 4 | 5 | 36.000 | 6.725 | 12.8 | 727.2 | 740.0 | 05.33 | 20.29 | 25.62 | 7 10 | 27 05 | 34 15 | 65.43 | 82.24 | 78.07 |
| 17 | 15 | . . | $Cu_2Cl$ | 4 | 5 | 33.500 | 5.855 | 14.2 | 904.8 | 919.0 | 05.52 | 21.99 | 27.51 | 7 36 | 29 32 | 36 68 | 67.83 | 89.14 | 83.85 |
| 18 | 15 | . . | $Cu_2Cl$ | 4 | 5 | 31.400 | 5.598 | 15.6 | 899.0 | 914.6 | 07.30 | 20.89 | 28.19 | 9 72 | 27 85 | 37 58 | 89.58 | 84.67 | 85 90 |
| 19 | 15 | . . | . . . . . | 4 | 5 | 29.000 | 5.160 | 22.2 | 963.0 | 985.2 | 06.49 | 20.62 | 27.11 | 8 64 | 27 48 | 36 12 | 79.64 | 83.55 | 82.57 |
| 20 | 15 | 4 | 2 | 4 | 5 | 76.800 | 10.000 | 12.4 | 418.8 | 431.2 | 08.24 | 17.38 | 25.62 | 10 98 | 23 17 | 34 16 | 101.19 | 70.44 | 78.09 |
| 21 | 15 | . . | $Cu_2Cl$ | 4 | 4 | 103.5 | 31.205 | 2.7 | 152.0 | 154.7 | 05.60 | 19.69 | 25.29 | 7 47 | 26 25 | 33 72 | 68.84 | 79.81 | 77.09 |
| 22 | 15 | . . | $Cu_2Cl$ | 4 | 4 | 37. | 5.760 | 16. | 897.8 | 913.8 | 06.12 | 21.43 | 27.55 | 8 16 | 28 57 | 36 73 | 75.20 | 86.86 | 83.97 |
| 23 | 15 | 1½ | $FeO\,SO_3$ ¼, $CuO\,SO_3$ ¾ | 4 | 4 | 36.5 | 6.053 | 23. | 906.2 | 929.2 | 08.06 | 22.57 | 30.63 | 10 75 | 30 09 | 40 84 | 99.08 | 91.48 | 93.37 |

| | |
|---|---|
| Assay value per ton, gold . . . . . . . . . . . . . . . . . . . . | $10 85 |
| Assay value per ton, silver . . . . . . . . . . . . . . . . . . . | 32 89 |
| Total . . . . . . . . . . . . . . . . . . . . . . . | 43 74 |

| | |
|---|---|
| Assay value per charge of 15 pounds, gold . . . . . . . . . . . . | $0 08.15 |
| Assay value per charge of 15 pounds, silver . . . . . . . . . . . . | 24.72 |
| Total . . . . . . . . . . . . . . . . . . . . . . . | 32.87 |

*Table showing the Results of Experiments upon Savage ore.*

| Number. | Amount of ore. | Chemicals. | | | Time. | Weight of— | | Fineness of bullion. | | | Actual value extracted. | | | Value extracted per ton. | | | Per cent. saved. | | Yield per cent. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Salt. | Sulphate of copper. | Quick-silver. | | Amalgam. | Bullion. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | Total. | Gold. | Silver. | |
| | *Lbs.* | *Oz.* | *Oz.* | *Lbs.* | *Hours.* | *Gramme.* | *Gramme.* | | | | *Cents.* | *Cents.* | *Cents.* | | | | | | |
| 1 | 15 | . . | . . . . . | 4 | 5 | 104.750 | 20.630 | 45.2 | 945.0 | 990.2 | 61.89 | 81.07 | 142.96 | $82 52 | $108 10 | $190 62 | 61.42 | 30.77 | 38.96 |
| 2 | 15 | 4 | 2 | 4 | 5 | 169.750 | 27.820 | 44.4 | 948.6 | 993.0 | 82.12 | 109.45 | 191.57 | 109 48 | 145 92 | 255 40 | 81.48 | 41.11 | 52.20 |
| 3 | 15 | 4 | 2 | 4 | 5 | 135.000 | 25.190 | 45.4 | 945.6 | 991.0 | 76.07 | 98.80 | 174.87 | 101 44 | 131 72 | 233 16 | 75.50 | 37.11 | 47.65 |
| 4 | 15 | . . | . . . . . | 4 | 6 | 115.60 | 19.120 | 58.0 | 928.0 | 986.0 | 73.71 | 73.63 | 147.34 | 98 28 | 98 16 | 196 44 | 73.15 | 27.66 | 40.15 |
| 5 | 15 | 1 | ½ | 4 | 5 | 86. | 15.930 | 64.4 | 933.0 | 997.4 | 68.17 | 51.48 | 119.65 | 90 88 | 68 64 | 159 52 | 67.64 | 19.37 | 32.60 |
| 6 | 15 | . . | $Cu_2Cl$ | 4 | 5 | 184.5 | 29.950 | 35.6 | 950.0 | 985.6 | 70.80 | 118.10 | 188.90 | 94 40 | 157 44 | 251 84 | 70.26 | 44.33 | 51.47 |
| 7 | 15 | . . | $Cu_2Cl$ | 4 | 5 | 181. | 30.030 | 34.6 | 951.4 | 986.0 | 69.02 | 118.50 | 187.52 | 92 04 | 158 00 | 250 04 | 68.57 | 44.80 | 51.11 |
| 8 | 10 | 1½ | $FeO\,SO_3$ ⅜, $CuO\,SO_3$ ¾ | 3 | 4 | 64.50 | 11.679 | 60. | 915.8 | 975.8 | 46.56 | 44.4 | 90.96 | 93 12 | 88 8 | 181 92 | 69.38 | 25.02 | 37.18 |
| 9 | 10 | 1½ | $FeO\,SO_3$ ⅜, $CuO\,SO_3$ ¾ | 3 | 4 | 85.4 | 15.571 | 47. | 929.4 | 776.4 | 48.63 | 59.87 | 108.50 | 97 26 | 119 74 | 217 00 | 72.39 | 33.74 | 44.35 |
| 10 | 10 | . . | $Cu_2Cl$ | 3 | 4 | 67.4 | 12.739 | 59.6 | 917.6 | 977.2 | 50.79 | 48.47 | 99.26 | 101 58 | 96 94 | 198 52 | 75.60 | 27.32 | 40.57 |
| 11 | 10 | . . | $Cu_2Cl$ | 3 | 4 | 62. | 11.950 | 59.6 | 917.6 | 977.2 | 47.64 | 45.46 | 93.11 | 95 28 | 90 91 | 186 19 | 70.92 | 25.64 | 38.05 |
| 12 | 10 | 4 | 2 | 4 | 5 | 87. | 15.450 | 40. | 934.8 | 974.8 | 41.06 | 59.94 | 101.01 | 82 12 | 119 88 | 202 00 | 61.12 | 33.78 | 41.28 |

| | | | |
|---|---|---|---|
| Assay value per ton, gold | $134 35 | Assay value per charge of 15 pounds, gold | $1 01.01 |
| Assay value per ton, silver | 354 87 | Assay value per charge of 15 pounds, silver | 2 66.81 |
| Total | 489 22 | Total | 3 67.81 |

*Notes accompanying the experiments upon the Kentuck ore.*

Nos. 1 to 20. Fifteen pounds of mercury added to the settler.

Nos. 21 to 23. Ten pounds of mercury added to the settler.

No. 3. No reason is known for the low yield both of gold and silver; the amalgam looked well, and the fineness was very high.

Nos. 8, 9, 10. These charges gave a higher gold return than any of the assays of the ore. No sufficient explanation can be assigned for the fact. The assays of the bullion were carefully repeated with the same results. Charge No. 10 shows the greatest difference between the assay and the yield, in which case it is less than fourteen mills' worth of gold in excess of the amount assumed from the assay to be present. This excess may probably be accounted for by errors in the manipulation that the ore was subjected to during the treatment in the pan and settler. It is possible that the mercury when strained yielded a trifle more gold than usual. The fact is worthy of mention that all the charges that show an excess of gold, with the exception of No. 20, follow each other consecutively.

Nos. 17, 18. The sub-chloride of copper was added in a solution of salt. The quantity of copper was equivalent to the amount contained in one ounce of the sulphate of that metal.

No. 23. The quantity of copper corresponded to two ounces of the sulphate of the metal.

*Notes accompanying the Experiments upon the Savage ore.*

Nos, 1 to 7. Fifteen pounds of mercury added to the settler.

Nos. 8 to 12. Ten pounds of mercury added to the settler.

No. 4. The pan by mistake ran six hours instead of five.

No. 5. No cause could be assigned for the low return of bullion.

Nos. 6, 7. The solution of sub-chloride of copper was the same as employed with Nos. 17 and 18 of the Kentuck ore.

Nos. 11, 12. The solution of sub-chloride of copper was the same as employed with No. 23 of the Kentuck ore.

It must be admitted that the results obtained in the above experiments are not, in all respects, satisfactory, nor do they point out conclusively the action and value of salt and sulphate of copper in the decomposition of the ar-

gentiferous ores by the Washoe process. They throw some light, however, upon several important points.

In considering the results, as shown in the tables, the most marked feature is the difference in the yield of the gold and silver bullion extracted from the two ores relative to their assay value.

There is, with but one exception, in every trial of the Kentuck rock a higher yield than the requirements of the mines demand of the mills, and, in most cases, it is very much larger than is usually returned under the most favorable circumstances, in practical operation. This is probably owing, in a great measure, to the large amount of mercury employed in proportion to the quantity of ore.

The Kentuck also gave as favorable results where mercury alone was used as when chemical agents were added. This proves very decidedly the ability of quicksilver aided by heat and iron to decompose the purer and easily reducible argentiferous minerals.

With the Savage ore it may be observed that the yield is in all cases not only very much below that from the Kentuck, but lower than the average returns from the mills upon ores that are not first subjected to a roasting process. This is undoubtedly due to the large percentage of blende and galena present, with which the precious metals are in combination. The use of chemical agents shows a decided improvement in the production of bullion from such ores as contain large quantities of base metals. The application of salt and sulphate of copper did not increase the loss of mercury, although in many charges large quantities were present in the pulp. In the experiments conducted, with every possible precaution to repeat the precise conditions of a charge, using the same quantities of salt, sulphate of copper, and mercury, the results differ as widely as in those cases where the amount of chemical agents employed are much less, or entirely abandoned. The cause of these great differences in the yield of bullion must be sought elsewhere than in the varying amounts of the chemical agents used, however important they may be, in certain cases, in aiding and assisting decomposition. A favorable yield undoubtedly depends more upon the native condition of the mercury than anything that is usually added to the pulp.

Charges 8, 9, 10, 11, of the Savage table, ran only four hours, which may

in some degree account for the low yield. Charge 12 ran five hours with a somewhat higher result. It should be stated that the mercury of charges 11 and 12 appeared to contain a small amount of lead, which may have rendered it partially inactive. Charges 21, 22, and 23, of the Kentuck table, were discharged at the end of four hours, without any marked decrease in the production of bullion. It seems probable that in the case of the latter the minerals are all easily reduced, and the amalgamation is practically accomplished in the allotted space of time. In the case of the Savage ore the base metals are but slightly attacked by the mercury, and require more time for any chemical changes before amalgamation can take place. There is considerable resemblance between Nos. 3 and 4 of the Savage table, with a large excess of salt and sulphate of copper, and Nos. 6 and 7 with a solution of the sub-chloride of copper. The reason may be found in the fact that in the former the chloride of copper formed would be quickly reduced by the iron to the state of the sub-chloride, and similar conditions produced as in the case of the latter.

Chemistry of the Process.—The action and value of common salt and sulphate of copper in the amalgamation of argentiferous ores, by what is known as the patio process, has always been a somewhat disputed question. Numerous theories have been advanced by metallurgists of long practical experience in Mexico, to account for the reduction of the sulphide of silver by the methods adopted in that country. The two which have obtained the most prominence, and which chemists have received with most favor, differ very widely in the manner the decomposition is supposed to be accomplished.

The most plausible theory, and the one now generally adopted, is that of Sonnenschmidt. He claims that the salt and sulphate of copper react upon each other, and produce sulphate of soda, which is neutral in its action, and chloride of copper. This latter salt then acts upon the argentiferous sulphide, and yields chloride of silver, sub-chloride of copper, and free sulphur. The sub-chloride reduces a second portion of the sulphide of silver, and causes the formation of an additional amount of the silver chloride, and sub-sulphide of copper. The silver salt is then attacked by the mercury; calomel, or sub-chloride of mercury, is produced, while metallic silver is set free, which combines with a second portion of the mercury, as amalgam.

The following chemical equations show the reactions:

$$NaCl + CuOSO_3 = NaOSO_3 + CuCl$$
$$2\ CuCl + AgS = AgCl + Cu_2Cl + S$$
$$Cu_2Cl + AgS = AgCl + Cu_2\ S$$
$$AgCl + Hg = AgHg + Hg_2Cl.$$

Bowring, an English metallurgist, on the other hand, denies that any of sulphide of silver is chloridized, and asserts that before amalgamation takes place, metallic silver is first produced. He claims that chloride of copper, in contact with mercury, forms the sub-chloride of both metals. The sub-chloride of copper, in contact with the oxygen of air, is converted into an oxychloride, which, in turn, acts upon the sulphide of silver, and liberates the metal in a free state, by oxidizing the combined sulphur. These reactions are expressed as follows:

$$2\ CuCl + 2\ Hg = Cu_2Cl + Hg_2Cl$$
$$Cu_2Cl + O = CuCl\ CuO$$
$$3\ (CuCl\ CuO) + AgS = Ag + SO_3 + 3\ Cu_2Cl.$$

Although oxychloride of copper may possibly be found at times, there does not appear to be any decided evidence that such is the case in practical operations, or that it decomposes the sulphide of silver, while the experiments already recorded show conclusively that both the chlorides of copper, under favorable circumstances, do chloridize the argentiferous sulphurets. The experiments, however, would seem to indicate that the action of the chloride of copper was much more intense than that of the sub-chloride.

The application and modification of the amalgamation process, as practiced in Washoe, has occasioned among experienced mill-men great doubt as to the beneficial results derived from the use of any chemical agents, at present mixed with the ore. This doubt is occasioned, or at least strengthened, by the growing custom of late years of decreasing the quantity of salt and sulphate of copper added to the charge, without apparently diminishing the product of bullion. Many amalgamators now abstain from the use of both reagents; others add a small quantity of the sulphate of copper, but no salt; in a few instances, the custom is to throw in only a little of the latter, while in many mills the rule is to employ a small amount of both substances, owing to a slight prejudice against the abandonment of "chemicals" altogether.

The action exerted by these two reagents in the pan would appear

clearly to indicate that the benefits derived from their use are partly to aid in converting the sulphide into chloride of silver, as in the patio, and partly to decompose such minerals as are but slightly attacked by the mercury. In the Washoe process, however, the large quantity of iron present must tend greatly to produce sub-chloride of copper almost as soon as the chemical agents are thrown into the pulp.

Notwithstanding the importance of common salt and sulphate of copper in the patio, and, under certain conditions in the pan, their value must be considered as only secondary in the decomposition of a large proportion of the Comstock ores. The advantages derived from their use are shown to be exerted chiefly upon such minerals as blende and galena, which are but slightly attacked by the mercury. But the amounts employed are in most cases too small to effect any very favorable results. On the other hand, if a sufficiently large proportion of the reagents are consumed in the pulp, in order to produce the beneficial returns, it is always at the expense of preserving the necessary purity of the mercury.

The quantity of salt deemed necessary by mill-men varies from one quarter of a pound up to seven or eight pounds per ton; scarcely any two establishments have the same rule. Its action upon the ore, without sulphate of copper, in producing any marked results may well be doubted.

The consumption of the sulphate of copper also depends upon the ideas of the amalgamators, but the amounts do not differ so widely as in the case of the chloride of sodium. It ranges from one quarter of a pound to three pounds per ton.

The addition of the sulphate, without salt, is of late years a common practice. The opinion among those who work their ore in this way is that it gives a little better yield than when mercury alone is employed, particularly where the ore indicates the presence of galena in any considerable amount, in which case it is said to quicken the mercury and render it more energetic.

Continued experience appears to determine this fact with a considerable degree of certainty. In working ores containing only a small percentage of lead the quicksilver very soon becomes dull and inactive, or, as it is technically termed, it sickens, and the yield from the pan is consequently low. Lead is one of the most deleterious metals in destroying the amalgamating energy

of mercury, and at the same time is very rapidly absorbed when the two metals are brought into contact. Sulphate of copper possesses, to a certain extent, the property of expelling lead from mercury, copper being amalgamated and sulphate of lead formed at the expense of the sulphuric acid of the copper salt.

If a concentrated solution of sulphate of copper be allowed to stand upon lead-amalgam the action takes place quite rapidly, mercury containing lead acting much more energetically upon the copper solution than when perfectly pure.

This salt, however, does not appear, under any circumstances, to possess the power of completely driving out the lead.

Another advantage derived from the addition of a small quantity of the sulphate of copper is that mercury, under certain conditions, when exposed to the solution, forms a minute amount of copper-amalgam, which causes the metal to act with a somewhat greater intensity in the decomposition of the silver sulphide than when perfectly pure.

Iron, as a reducing agent, in the pan process, probably plays an important part in bringing about the favorable results obtained. This may occur in three ways:

First. It aids, in a great measure, the decomposition of the chloride ot silver.

Secondly. It reduces the calomel formed during the operation; the chlorine, combining with the iron, goes into solution, and the heavy metal is liberated. In this way it not only prevents a chemical loss of mercury but also serves to keep the surface of that metal bright and clean, which otherwise might be coated with a thin film of sub-chloride, which would greatly destroy its activity.

Thirdly. It undoubtedly assists directly in the amalgamation, where the two metals are brought into close contact with the easily reducible sulphurets. The successful and continued operations in Washoe, without the aid of any other chemical agents, sufficiently prove this statement. The experiments already cited in treating argentite and iron filings with mercury confirm the fact.

Humboldt, in speaking of the amalgamation problem in Mexico, draws attention to this point and remarks upon the rapidity with which amalgamation was secured when the two metals were triturated together with argentite. This action of iron is obtained not only from the constant agitation maintained, which brings the pulp and metal in contact with the sides and bottom of the

pan, but also from the amount of iron disseminated, in a fine condition, through the ore, produced by the wear of the stamps, shoes, and dies.

This consumption of metal from the batteries and pans varies very much in the different mills, depending partly upon the details of construction and grinding effects of the pans and partly upon the hardness of the castings employed. The following figures from two mills serve to show the quantity of iron reaching the pulp from this source, per ton of ore worked. The quantity of ore treated is sufficiently large to afford a very fair estimate of the metal consumed:

| Tons of ore worked. | Loss of iron in batteries. (Pounds per ton of ore.) | Loss of iron in pans. (Pounds per ton of ore.) | Total. |
|---|---|---|---|
| 14,000 | 2.78 | 9.42 | 12.20 |
| 12,236 | 2.10 | 7.14 | 9.24 |

The fine iron coming to the ore in this way is very considerable in proportion to the other minerals present. If ten pounds per ton are added from this source it is equal to one-half of one per cent. In the Kentuck ore, of which an analysis has been given, there is, including the iron from the batteries, less than two and one-half per cent. of ore-bearing minerals present.

Mercury and iron, under the proper conditions, undoubtedly are the principal agents in the extraction of the precious metals by the Washoe method. The results depend, however, in a great measure, upon the mechanical treatments employed to reduce the ore to an exceedingly fine state of division, and to maintain, with the proper degree of consistency, a constant agitation of the entire mass; the essential conditions of the amalgamation being that the mercury should be thoroughly incorporated in the pulp, and every particle of the reducible minerals brought in direct contact and triturated with the metal, in the manner so well accomplished by the friction and grinding action of the pan. The mercury should also at all times retain a bright, clean surface, free from any film of metallic salts, such as sub-chloride of mercury or sulphate of lead, and any coating of oil or grease. The slightest tarnish appears to retard very greatly the activity of the metal. The iron seems to act as an electro-chemical agent; the immediate contact of the two metals, aided by heat and fric-

tion, causing a local electric current, which renders the amalgamating energy of the mercury much more intense.

Mercury, when perfectly pure, does not apparently possess to so great an extent the power of taking up other metals, or of decomposing mineral combinations, as when it holds a minute quantity of some foreign metal in solution. The experience among amalgamators in Mexico is that the yield of gold is increased by the presence of silver; also, that the latter metal is extracted with greater facility if a considerable proportion of the amalgam is already present. This opinion is held by most mill-men in Washoe.

It is stated by some writers upon the question that silver is absorbed with increased activity when copper is employed, and as the former is amalgamated the latter will be expelled. Both iron and copper cause the formation of copper-amalgam. On the other hand sulphate of copper exhibits a tendency to drive out lead.

Karsten mentions the property of this salt to purify the mercury from both zinc and antimony. Any one who has witnessed the intensity which sodium-amalgam exerts cannot fail to have been impressed with the rapidity with which it attacks gold, silver, and silver compounds; yet its application in Washoe in practical operations did not give such results as would warrant its general introduction in the process.

Although the presence of a small quantity of several metallic bodies enhances the amalgamating energy of the mercury, yet a slight excess "sickens" it; that is, it loses its fluidity and becomes dull and inactive. The peculiar phenomena attending the mercury, by which both electro-positive and electronegative metals are absorbed, and the effects which they produce in increasing or neutralizing its action, are very little understood.

The loss in quicksilver during the operation arises from two sources; the one mechanical, the other chemical. The former depends largely upon the manner in which the final washing from the pulp is conducted; the separation being more or less perfect according to the skill and care with which it is executed. A considerable quantity of the metal, however, is so cut up and ground to such a fine state of division that it is impossible to save it. The chemical loss is occasioned by the formation of the chlorides of mercury, which escape with the tailings.

In the patio the chemical loss is frequently very considerable; the amounts of common salt and magistral employed are large, while, at the same time, there is no reducing agent present to act upon the calomel formed, as is the case in the pan. In the patio the loss is said to increase in proportion to the richness of the ore in the sulphurets of silver, owing to the fact that for every atom of chloride of silver reduced by the mercury a corresponding atom of the latter metal is consumed as sub-chloride.

In the Washoe process the chemical loss would seem to be small in proportion to the entire consumption. This is probably due to the beneficial effects of the iron, which combines with the chlorine of the calomel, setting the quicksilver free.

The more the metal is ground the more it must be cut up, and the greater the difficulty in recovering it. Now, if the consumption of iron is assumed to measure the grinding effect exerted by the pan, the relation between the loss of mercury and that of iron should be, in a certain degree, proportional.

The following table, compiled from the results of several mills, furnishes some interesting details in regard to the loss of mercury:

Part 1 shows that the loss of mercury is independent of the consumption of chemical agents.

Part 2 shows that the loss of mercury is, in some measure, dependent upon the consumption of the iron of the pan.

| Tons of ore. | 1. | | | | 2. | |
|---|---|---|---|---|---|---|
| | Pounds per ton of ore. | | | | Pounds per ton of ore. | |
| | Salt. | Sulphate of copper. | Sulphuric acid. | Mercury. | Iron. | Mercury. |
| 5,400 | - - | 0.33 | 0.18 | 1.54 | 9.42 | 1.54 |
| 8,605 | - - | 1.74 | 0.31 | 1.39 | 9.79 | 1.38 |
| 4,713 | 0.23 | 1.52 | - - | 1.34 | 9.39 | 1.38 |
| 35,000 | 9.00 | 3.00 | - - | 1.33 | 7.50 | 1.33 |
| 7,523 | - - | 1.38 | - - | .79 | 7.14 | 1.00 |

The following is the result of an analysis of some artificial crystals of Washoe amalgam:

| | |
|---|---|
| Mercury | 75.04 |
| Silver | 24.18 |
| Gold | .77 |

They have the composition very closely of three atoms of mercury to one of silver.

From the foregoing considerations of the principal features of the Washoe process it appears—

That the ore consists chiefly of native gold, native silver, and argentiferous sulphurets, associated with varying proportions of blende and galena.

That the action of chloride of sodium and sulphate of copper in the pan produces chloride of copper.

That the presence of metallic iron necessarily causes the formation of the sub-chloride of copper.

That both the chlorides of copper assist in the reduction of the ore by chloridizing the sulphurets of silver, and in decomposing the sulphurets of lead and zinc.

That sulphate of copper enhances the amalgamating energy of mercury, by causing the formation of a small quantity of copper-amalgam. It also tends to expel the lead.

That notwithstanding the importance of chemical agents, as above indicated, the quantities added to the pulp in the ordinary practice of Washoe mills are too small to effect any very beneficial results.

That mercury and iron, aided by heat and friction, are the principal agents in the extraction of the precious metals by the Washoe process.

That the essential conditions in the amalgamation of the gold and silver are that the mercury be kept perfectly bright and pure, in order to produce a direct contact of that metal with the iron and sulphide of silver.

That the consumption of mercury in the Washoe process may be considered chiefly a mechanical, and, only to a limited extent, a chemical, loss.

# CHAPTER VI.

## CENTRAL AND EASTERN NEVADA.

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## SECTION I.

### MINING AND MILLING IN WESTERN NEVADA.

The discovery and early development of the Comstock lode in 1859 and 1860 gave a fresh impulse to the spirit of exploration throughout Nevada, and this was soon followed by the announcement of new silver-producing regions. In 1861 the mining districts, first opened in Humboldt County, about 150 miles northeast of Virginia City, attracted great attention, and a year later the Reese River discoveries succeeded these, creating still greater excitement. From these points, as centers, small exploring parties radiated in almost every direction, and each succeeding year witnessed the discovery of one or more new mining districts. Since that time nearly every mountain range in the State has undergone either much or little examination at the hands of the prospector. Regions, until lately, almost totally unknown have become familiar, while others that were so remote from the business centers of the Pacific coast as to be practically inaccessible for industrial pursuits have now been brought into comparatively easy communication with either coast by the completion of the Pacific railroad; and although the day for new and impor-

tant discoveries of mineral wealth has by no means passed, as the late developments at White Pine and in Southern Nevada plainly show, a fair idea of the general features and resources of the State has been obtained.

Many of the newly discovered districts that were at first deemed most important have since proved to be bitter disappointments; others, though found to contain many productive veins and deposits of great value, must await cheaper labor and materials in order to be worked profitably; but a sufficient number have been successfully developed to establish the fact that the State possesses in its mineral veins the broad and substantial basis of a permanent mining industry.

It will not be attempted in this chapter to give a description of all the mining districts that have been organized in the State and sufficiently developed to make them well worthy of attention. The late reports of J. Ross Browne, esq., United States Commissioner of Mining Statistics, and his successor, R. W. Raymond, esq., cover much of the ground and furnish in their descriptions a great deal of information concerning many of them. The writer prefers to confine himself to some account of the more important and most developed localities to which he was able to give his personal attention, and even in so doing, to endeavor, by describing typical mines, the extent and method of their development, and the processes employed for the treatment of their ores, to convey a general idea of the condition of the mining industry, rather than to make especial mention of every mine or mining district that might be considered worthy of it.

The main features of the topography and geology of the State have been already briefly referred to in a foregoing chapter; in which, also, the position of the principal mining regions and their relations to each other have been somewhat noticed. In this chapter the several districts described will be taken up in nearly the order in which they might be visited by one crossing the State from west to east.

The western part of the State, north of the Washoe region, contains some mining districts that have attracted attention from time to time, but which, so far as development or the production of valuable metals are concerned, have not yet attained much importance. An example of this class is the Peavine district, about 30 miles northwest from Virginia City, and seven

or eight in the same direction from Reno, on the railroad, in which some veins of copper ore have been opened in metamorphic rocks, and prospected to a depth of 40 or 50 feet. The surface ore consists chiefly of oxides and carbonates, with some sulphurets of copper. It is slightly argentiferous. The region has been lying neglected for several years, but its proximity to the railroad may make it an available source of copper should future exploration encourage further development.

MONTEZUMA MINE.—Passing over these localities, that are yet of minor importance, we come to the Trinity Mountains, which have been the scene of some extensive and interesting mining and metallurgical operations. This range of mountains is on the west bank of the Humboldt River, which here runs in a southerly direction. The principal mine is the Montezuma, the owners of which have expended a large sum of money in the development of their property, and in the construction of metallurgical works for the treatment of their ores.

These operations were chiefly conducted under the direction of Mr. A. W. Nason, to whom the writer is indebted for much of the information here given concerning them.

The Montezuma ledge, chiefly owned and for some time worked by the Trinity and Sacramento Mining Company, is situated in the eastern foothills of the Trinity range. The mine is about three miles west, a little northerly, from Oreana, a station on the Central Pacific Railroad, 262 miles from Sacramento, and the location of the company's smelting works. The ledge is in a low hill, the ridge of which is nearly parallel to the trend of the main range and separated from it by a shallow longitudinal valley, having nearly a north-northeasterly and south-southwesterly course. The course of the ledge crosses the trend of the hill diagonally, being north 88° east, true. It dips to the northward with an inclination of 40 or 45 degrees.

The inclosing rock of the vein may be generally described as porphyry, though it is probably closely related to, if not identical with, the granitic rocks that occur higher up in the range. This granite is overlaid by limestones and slates, which sedimentary beds are found also not very remote from the Montezuma. The vein was discovered by means of an outcrop of the ore on the western slope of the hill referred to, and a pit or excavation was sunk on

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the vein at that point, from which a considerable quantity of good ore was taken. At the date of the writer's visit it had been explored by a cut along the course of the vein from west to east, partly open and partly in tunnel, having a continuous length of about 170 feet, and being about 30 feet below the surface at its deepest part; while below the level of the cut, and starting from it, a shaft had been sunk, measuring on the plane of the vein 120 feet in depth. Beyond the cut, along the course of the lode, are several other disconnected pits extending the general explorations of the vein over a length of 500 or 600 feet. The total length of the company's claim is 2,000 feet.

The outcrop of the vein, as exposed in the long cut, had a width in places of 20 feet, averaging, perhaps, from the surface to the level of the cut, about 10 feet. Below the cut, in the shaft, the average width was about 6 feet between the walls. Along the cut the ore is said to have formed a solid mass, almost entirely filling the space between the two walls; and the sections exposed at the time referred to accorded with that statement, the vein being filled with ore, variable in quality but almost entirely free from gangue, and nearly all fit to send to the furnace without assortment. The cut at that time was not deep enough to give a clear exhibition of either wall, unaltered by surface influences. The hanging wall is covered by an accumulation of loose earth and soil several feet in thickness, and below this the wall-rock itself is decomposed and doubtless considerably changed from its original character. Between the wall-rock and the vein on the hanging side is a seam of soft white clay, eight inches or a foot in thickness. On the foot-wall below the vein there is a soft, white, brecciated mass, clayey in character, but penetrating the country-rock, as if the mass of the latter in the neighborhood of the vein had been thoroughly changed. Further south, on the surface, are found deposits of ore and vein-material, indicating the existence of seams or branches of the vein in the foot-wall.

In the shaft, which is 120 feet deep, measured from the level of the cut on the inclination of the vein, the walls are well defined. The vein is about six feet wide. For 60 feet of the depth above named the shaft passed through ore, filling the vein from wall to wall. Below that point the walls of the vein continued as above, but the inclosed material was found to consist chiefly of gangue with little or no ore. Developments up to that period indicated that

the shaft had passed through the lower limit of the ore-chimney. At the point where the vein ceased to be ore-bearing in the shaft, a drift was subsequently run westward some 80 or 100 feet, which was reported as being in good ore for the whole distance.

The ore is of a peculiar character. It consists chiefly of the oxides of lead and antimony, carrying a small percentage of silver, averaging, *by assay*, about $80 per ton. The ore, as it now exists, is evidently the result of decomposition or alteration of other and more familiar forms of silver-bearing, antimonial ores. It is sometimes hard, massive, and compact in character, while the larger proportion is friable, showing a fibrous structure, apparently the form of its pre-existing condition. The harder variety is usually next the hanging wall and needs blasting, while the other kind, lying on the foot-wall, may be removed without the aid of powder. The former is said to be the richer. An analysis of a piece of this ore, made by Mr. William G. Mixter, assistant at the Sheffield Laboratory, Yale College, gave the following results:

| | |
|---|---|
| Antimonic acid, $SbO_5$ | 51.94 |
| Oxide of lead, $PbO$ | 40.89 |
| Silver, $Ag$ | .33 |
| Sesquioxide of iron, $Fe_2O_3$ | .60 |
| Insoluble residue | 1.66 |
| Water | 4.58 |
| | 100.00 |

The above composition, together with the physical characteristics of the ore, identify it with bindheimite, a mineral described by Dana, occurring in Cornwall, Siberia, and other localities, and derived from the mineral jamesonite by decomposition. A few fragments of undecomposed mineral, strongly resembling jamesonite, were found by the writer in the ore at Oreana.

Thus far the extraction of the ore has been a simple process of quarrying in the open cut, and has been done very cheaply. It is said to cost not more than $2 or $2 50 per ton for extraction; mining, and hauling to the furnace, costing, in the

aggregate, $4 or $4 50 per ton. Little or no expense for timber has been incurred and no hoisting machinery employed so far. The mine is quite dry, as is the surrounding country, all the water required for domestic purposes being brought from the river, three miles away. This is but little, as five men at the mine were able to supply the furnace, of 12 or 15 tons capacity, with ore, and the teams employed in hauling ore were accustomed to carry back sufficient water on their return trips.

The superintendent of the works, Mr. Nason, estimated the supply of ore in the mine at 10,000 tons, the estimate being based on the length of lode exposed at the surface and the average depth assumed from that in the shaft. At the date of the writer's visit the ascertained facts concerning the continuance in depth of the ore-body were not sufficient to place this estimate beyond question, but the developments thus far made indicated the existence of a large supply.

In the neighborhood of the Montezuma, within the district known as Arabia, are a number of other ledges carrying ore like that just described, but lower in value and less in quantity. The locations made on these ledges are numerous, and considerable work has been done on some of them, showing that they occur in series parallel to each other but quite small individually, many seeming to pinch out altogether in depth. Their general course is different from that of the Montezuma, being north and south, or nearly so.

The ledge that has been most developed and seems to promise most favorably, next to the Montezuma, is the Jersey, which has a northerly course, and if both veins are continuous, should intersect the Montezuma at no great distance from the workings on the latter. It has been traced for several hundred feet on the surface and explored by inclines to the depth of 100 feet. Its ore has not thus far been as rich as that of the Montezuma, but it is believed that it can be worked with profit, especially with the increased advantages secured by the Pacific railroad, which passes within two or three miles of the property.

Montezuma Furnaces.—The Trinity and Sacramento Company prosecuted their mining and metallurgical operations very vigorously during two or three years previous to the autumn of 1868. The mine was opened as already described, and a large amount of money was expended in providing smelting works

for the reduction of the ore and extraction of silver. This establishment had hardly been completed and entered upon the regular performance of its work to the full extent of its capacity, when the company, already deeply involved in litigation, became embarrassed financially and their work was suspended;[1] although it appears from the accounts of the mine that, up to the time referred to, the average yield of the ore was largely in excess of the costs of mining and smelting.

The method of treatment of the ores, at the time when the work was in active progress and before the completion of the Pacific railroad, presents some novelties, and is worthy of a somewhat detailed description, notwithstanding the fact that a portion of it is no longer in use.

In the early history of the enterprise a ten-stamp mill, furnished with three grinding and amalgamating pans, was provided with the intention of treating the ores by the ordinary Washoe method; but as this was soon found to be quite unsuited to the character of the ore it was abandoned, and furnaces for smelting and refining were constructed. This process consisted of smelting the ore in a shaft-furnace, by which means crude metal was obtained, amounting to 45 or 50 per cent. of the charge of ore, and consisting of lead, antimony, and silver; the last named being contained to the value of $160 or $200 to the ton of metal. The metal was then subjected to treatment in a calcining, or sublimation, furnace, by which means the antimony was removed, and the lead consequently enriched by concentration, until it contained from $300 to $400 per ton in silver. From this lead the silver was then extracted by cupellation in an English cupel-furnace. Among the products of the sublimation-furnace was an alloy of lead and antimony, marketable in San Francisco at a remunerative price for the production of type-metal. The accompanying plates, illustrating the construction of the furnaces and their general arrangement, were prepared from drawings made by Mr. Sydney Tuttle, assistant superintendent of the works, and kindly placed at the disposal of the writer.

The shaft-furnace, employed for the smelting of the crude ore, is shown by Figs. 1, 2, 3, and 4, on Plate XXV. Figs. 1 and 2 show a front and side

[1] According to newspaper reports the mine and smelting furnaces were again in operation in August, 1870.

elevation; Fig. 3 a horizontal section through *A B*; and Fig. 4, a vertical section through *C D* of Fig. 1. The total height of the furnace is about 40 feet. The hearth is built of stone, cut from trachytic rock that occurs a few miles south of the works. The shaft is of common brick with a lining of fire-brick from the hearth up to the throat.

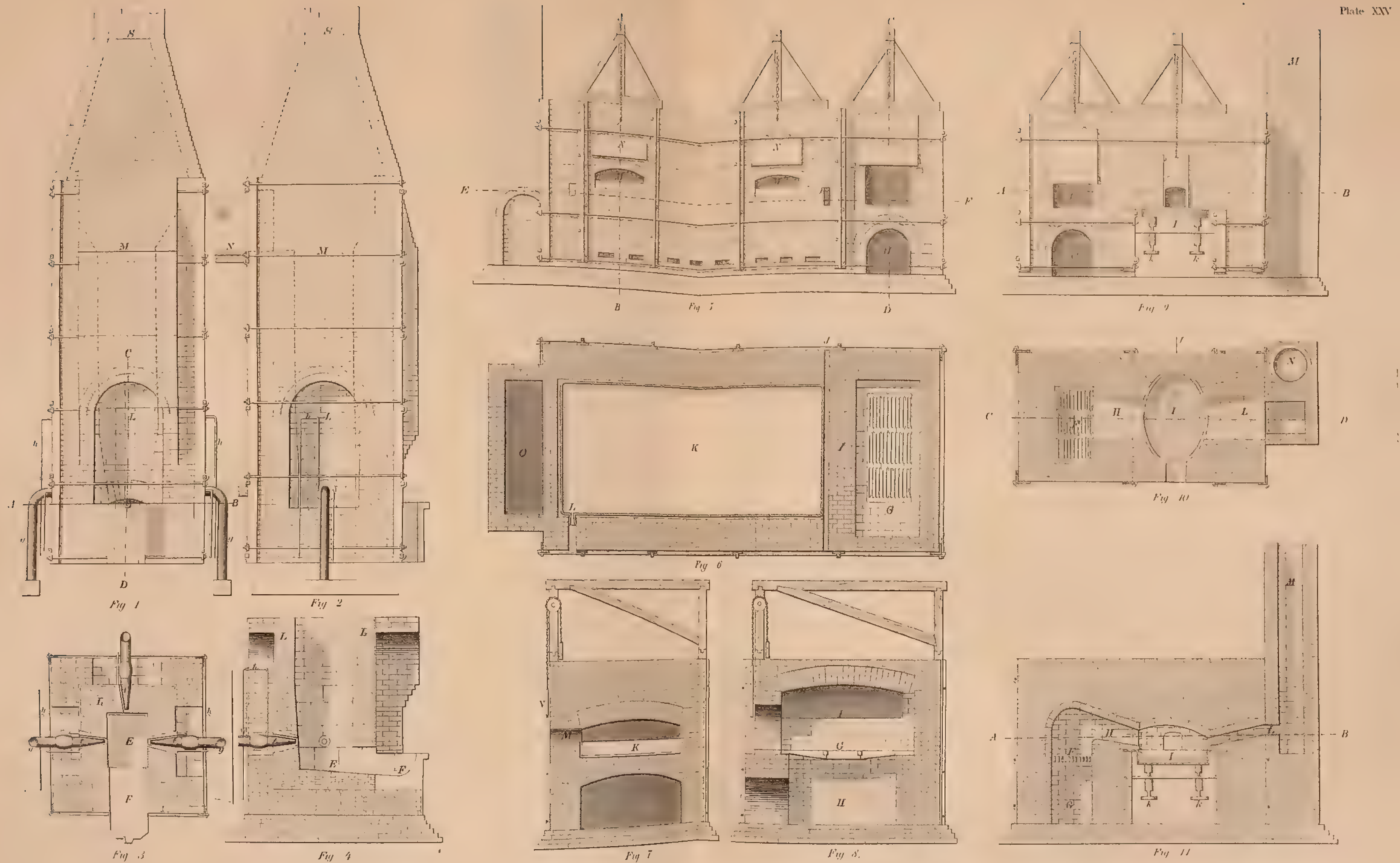
In the drawings, *E* is the hearth, or sole; *F*, the sump, or receiver, into which the metal runs on being tapped from the furnace; *t*, tuyeres; *g*, blast-pipes; *h*, pipes to supply water to the tuyeres; *L*, lining of the furnace; *M*, throat; *N*, floor for feeding ore; *S*, stack.

The capacity of one of these furnaces is from 12 to 13 tons per day of twenty-four hours. The ore being broken into small pieces is spread upon the charging floor and mixed with flux. This sometimes consists of limestone, but generally of slag, or both together. Litharge, the product of the cupelling furnace, is also sometimes used with fresh ore. The ore for the charge, being mixed with about 25 per cent. of flux, is supplied to the furnace with a sufficient quantity of charcoal, that averages about 15 bushels to the ton of ore. About 100 pounds of the mixed charge and coal is fed to the furnace at once, the supply being continuously kept up as the operation of smelting proceeds. The blast is supplied by a fan-blower which is driven by the steam-engine formerly provided for operating the stamping and grinding machinery in the old mill.

When the furnace is in regular operation the slag is discharged continuously, while the metal is tapped off, at intervals of an hour or two, into an iron receiver, whence it is dipped out and cast in pigs or ingots of convenient size for further handling.

The yield of metal, consisting of lead, antimony, and silver, is from 45 to 50 per cent. of the ore smelted; one furnace smelting 12 tons of ore in a day, supplying consequently about 5 tons of crude metal. The ore, originally containing $80 per ton in silver, yields metal which contains from $150 to $200 per ton. The slags are constantly examined. Usually they are quite poor, but if found to contain an available percentage of metal are broken up and returned to the furnace with a fresh charge of ore.

The consumption of charcoal in this smelting process is usually about 15




Scale $\frac{1}{48}$

bushels to the ton, but sometimes exceeds that quantity. It is made from the nut-pine, and is brought chiefly from what is locally known as the East Humboldt Range, 28 or 30 miles distant from the works. It costs, on an average, 50 cents per bushel. Its quality is considered to be excellent. There are limited supplies of the nut-pine nearer to the works, furnishing small quantities of charcoal, but in the more remote range, above mentioned, the supply is represented as quite sufficient for a long time, at the present rate of consumption.

There are two blast-furnaces, like that just described, one of them being held in reserve for any emergency by which the other may be disabled. One furnace in steady operation could fully supply the refining furnaces that were in use at the time of the writer's visit.

The refining or calcining furnace for the sublimation of the antimony contained in the crude metal, and the consequent improvement of the lead, consists at these works of a bath, or cast-iron pan, about 13 feet long by 5 feet 8 inches wide and 8 inches deep, the metal being an inch thick. The pan is set in brick-work, the construction of which is shown by an elevation, a plan, and transverse sections on Plate XXV, Figures 5, 6, 7, and 8. Fig. 5 is a side elevation; Fig. 6, a horizontal section through *E F* of Fig 5; Figs. 7 and 8, transverse sections through *A B* and *C D* of Fig. 5.

The pan rests on a substantial foundation and is inclosed by side-walls, of common bricks, about 10 inches high, over which an arch is turned, as shown in the section. A narrow space is left between the pan and the inclosing masonry to allow for expansion. At one end of the structure is a fire-place and ash-pit; the flame passes over a bridge, which separates the fire-place from the pan, and thus over the surface of the metal contained in the pan, toward the stack at the opposite end. There is a horizontal channel passing through the bridge, behind the pan, opening at the sides of the furnace and communicating by vertical passages with the interior, by which means air may be admitted to the charge. Doors are provided in the side of the furnace for the purpose of skimming off a crust, or scum, consisting of lead and antimony, that collects on the surface while the operation of calcining is in progress. The charge is also introduced through these doors. There is a tap near the end of the pan on one side, for the purpose of draw-

ing off the refined metal. At the base of the stack is a chamber for the collection of the oxidized antimony that may condense in the stack and fall to the bottom. The whole structure is firmly bound together by irons and bolts, as shown in the drawings. In the figures, *G* is the fireplace; *H*, the ash pit; *I*, the bridge; *J*, the air-channel through the bridge; *K*, the pan; *L*, the spout; *M*, the openings for putting in and working the charge; *N*, the doors; *O*, the chamber at base of stack for the accumulation of the oxidized antimony.

To set this furnace in operation the metal may be first melted and introduced in a fused state to the pan; or, what is more common, the pan is heated to redness and the pigs of crude metal are laid upon the pan-bottom, when melting ensues. The fire may be quite moderate, the only fuel used in this case being sage brush. The antimony is oxidized and passes up the stack, a part to escape, a part condensing in the chimney. The charge of the pan at the outset is some six or eight tons, but as the molten metal, diminishes in bulk by the sublimation of the antimony, new bars are added to keep up the supply. A scum collects on the surface of the molten metal which is removed by scrapers from time to time. This consists chiefly of lead and antimony with very little silver. While this refining process was still practiced at the works, these skimmings were collected, re-melted, and cast in bars, to be sold in San Francisco for type-metal, Babbitt-metal and other purposes. The alloy consisted of 71 per cent. of antimony with 29 per cent. of lead and was worth 8 cents per pound.

The lead in the pan is gradually enriched by this method of concentration, and assays are taken from time to time, usually at intervals of twelve hours, for the purpose of watching the progress of the operation. When the value of the lead has been brought up to about $350 or $400 per ton, it is drawn off in molds and then subjected to treatment in the cupel-furnace.

The following series of assays, taken during the progress of one run of metal shows the gradual improvement of the lead:

| | |
|---|---|
| March 10, raw metal at time of charge, value per ton | $209 68 |
| 10, twelve hours later, value, per ton, of contents of bath | 214 04 |
| 11 ........do........do........do | 219 44 |
| 11 ........do........do........do | 238 93 |

| | | | | |
|---|---|---|---|---|
| March 12, twelve hours later, value, per ton, of contents of bath | | | | $248 68 |
| 12 | do | do | do | 253 60 |
| 13 | do | do | do | 263 36 |
| 13 | do | do | do | 273 12 |
| 14 | do | do | do | 279 94 |
| 14 | do | do | do | 282 76 |
| 15 | do | do | do | 287 58 |
| 15 | do | do | do | 292 56 |
| 16 | do | do | do | 297 22 |
| 16 | do | do | do | 302 31 |
| 17 | do | do | do | 311 68 |
| 17 | do | do | do | 321 82 |
| 18 | do | do | do | 336 44 |
| 18 | do | do | do | 346 40 |
| 19 | do | do | do | 346 40 |
| 19 | do | do | do | 351 08 |
| 20 | do | do | do | 355 96 |
| 20 | do | do | do | 365 70 |
| 21 | do | do | do | 375 20 |
| 21 | do | do | do | 378 40 |
| 22 | do | do | do | 385 22 |
| Total quantity of crude metal charged 20.8 tons. Value | | | | 4,584 89 |
| Total quantity of refined metal tapped 11.9 tons. Value | | | | 4,541 12 |

Loss by sublimation and skimmings, 42.78 per cent. of total weight of crude metal.

Loss in silver 0.97 per cent. of total value of silver contained in the metal.

The calcining furnace in which the foregoing run was made was 10 feet long by 5 feet wide. The capacity of those subsequently introduced, and such as have been described in these pages, is said to be equal to the treatment of two tons of crude metal per day, yielding at the rate of about one ton of rich lead for twenty-four hours. There are four of these furnaces at the works. The pans were cast in San Francisco and brought over to Nevada at a large cost for freight. Much trouble was at first experienced owing to leaks in the pans, by defective casting, involving great expense and loss of time in taking them out for repairs, but they were ultimately brought into a very efficient condition. The cost of calcination is stated at $8 per ton of ore.

The cupelling furnace is of the kind commonly used in England. Figs. 9, 10, and 11 on Plate XXV show the method of its construction. Fig. 9 is a side elevation; Fig. 10, a horizontal section on the line *A B* of Fig. 9; and Fig. 11 is a vertical section on the line *C D* of Fig. 10. *F* is the fire-place; *G*, the ash-pit; *H*, the bridge; *I*, the test-ring or hearth; *J*, the tuyere; *k*, *k*, supporting and adjusting screws for the test-ring; *L*, the flue leading to the stack, *M*; *N*, a melting pot or pan in which the metal may be prepared for the hearth.

The hearth consists of bone-earth, prepared from the bones of cattle, which lie in profusion along the track of the old emigrant road, furnishing an abundant supply. The bones are burned and then pulverized in the stamp mill; and being moistened with water that contains a little alkali, leached from wood ashes, the mass is beaten compactly into the test-ring. This is oval in form, being 4 feet long by 3 feet wide. It is a rim of iron, 7 or 8 inches deep, having bars across the bottom to sustain the hearth of bone-earth. The latter being prepared in the rim it is very carefully dried, and the ring is then introduced into the cupel-chamber, supported upon screws, by means of which it may be elevated or lowered, or inclined in one direction or another. When properly adjusted, it is heated, very gently at first, in order to avoid cracking. The heat from the fireplace, passes over the bridge into the cupel-chamber and thence by the flues to the stack. When the hearth is well heated the lead is placed upon it and a blast of air is introduced by means of a fan-blower and tuyere. This acting upon the surface of the lead, the metal is oxidized, and the resulting litharge is allowed to run off through gutters made for its passage, in the surface of the hearth, into vessels placed below for its reception. As the lead is gradually oxidized, fresh supplies of metal are introduced, either in the form of pigs, or in a molten state, the pan, *N*, being provided for the purpose of fusing the metal, if desired. By this means the metal on the hearth is constantly enriched; and when the button of accumulated silver has become as large as may be desirable, the addition of lead is discontinued and the oxidation carried on until the lead is nearly all removed, leaving a mass of silver, of a high degree of fineness, upon the hearth. The litharge produced by this operation contains some

silver. The richer portion is returned to the shaft-furnace and mixed with the charge of fresh ore. The cost of cupellation is stated at $5 per ton of ore.

It is stated as a result of a long-continued operation that from 90 to 95 per cent. of the assay value of the ore was extracted by the method of treatment above described.

The general cost of the reduction of the ore, at the date of the writer's visit to the works, is given in the following statement. These expenses have been somewhat reduced since that time by the completion of the Central Pacific railroad, and consequent cheapening of supplies and labor. It may also be observed, in this connection, that the increased facilities of transportation from Oreana to San Francisco, secured by the completion of the railroad, induced the manager of the works to dispense with the refining process at Oreana some time before the total suspension of operations. The ore was smelted in the shaft-furnace, as already described, for the production of crude metal, which was then shipped without refinement to San Francisco, where it was subjected to methods of separation or sold for export.

*Expenses of Smelting Furnace per day.*

| | |
|---|---|
| Two smelters and two helpers | $16 00 |
| Two breakers | 7 50 |
| Two feeders | 8 00 |
| Two engineers | 8 00 |
| Fuel for engine—furnished on contract | 16 00 |
| Chinaman—general laborer | 2 00 |
| General expense | 2 00 |
| Smelting 13 tons per day, costing | 59 50 |
| Cost of smelting, as given above, per ton | 4 57 |
| Charcoal, 18 bushels per ton, at 50 cents per bushel | 9 00 |
| Estimated repairs per ton | 50 |
| Mining and hauling per ton | 4 50 |
| Superintendence and general account per ton | 3 00 |
| | 21 57 |

To this was at that time added—

| | |
|---|---|
| For calcining, per ton of ore | $8 00 |
| For cupelling, per ton of ore | 5 00 |
| Making total cost of treatment, per ton of ore | 34 57 |

The average yield in silver alone, without taking into account the base metals, was then about $70 per ton of ore.

The foregoing statement, showing a cost of $21 57 per ton for reduction of the ore without refining the product, is the result of experience in 1867, since which time important abatements have been made; but accepting that as an estimate for the present, we have as the cost of a ton of crude metal, $44, since the result of smelting more than 1,800 tons of ore shows a product of 983 pounds of metal per ton, or 49 per cent. Adding $30 per ton, freight to San Francisco, to the cost of production, we have $74 as the cost of laying down a ton of the metal at the market; against which we have the value of base metal, per ton

| | |
|---|---|
| have the value of base metal, per ton | $100 00 |
| Silver—say 100 ounces, at $1 | 100 00 |
| Making a total of | 200 00 |

Unionville and vicinity.—Northeast from Oreana, 28 miles distant by way of the traveled roads, is Unionville, the county town of Humboldt County, and the central point of an important mining district. The town is now accessible by wagon road from the station of the Central Pacific railroad known as Mill City, 296 miles from Sacramento. Unionville is 21 miles by stage road south of the station referred to. It is situated in one of the cañons of the eastern slope of what is locally termed the West Humboldt range of mountains. This range, rising in the south near the "sink," or basin, of the Humboldt River, extends northerly to the "big bend" of that river, which there, cutting through a break in the range, makes a sharp turn in its westward course, and flows to the south, having the range of mountains referred to on the left, or east, bank and the Trinity mountains on the right, or west, bank. The higher points of the range reach an altitude of 5,000 or 6,000 feet above the river at its base, and over 10,000 feet above the level of the sea. Many of

its cañons are well watered and its slopes bear a moderate supply of nut-pine and cedar, suitable for fuel. The mining region, of which Unionville is now the center, was the scene of great activity in the years first succeeding the advent of prospectors and miners into this part of the State. The discovery of silver-bearing lodes in these mountains was made not long after the earlier developments of the Comstock lode, and for a season was the occasion of great excitement. The range, for many miles of its length, was visited by explorers, who have left abundant evidence of their industry in innumerable prospecting holes that dot all the hillsides. Many mining districts were formed, thousands of locations made, towns built, and large amounts of money expended; and when the extravagant hopes of speculators or their victims met with the disappointment that was inevitable, nearly the entire population, only excepting a few who were determined to persevere and a few more who, for want of means to get away with, were forced to remain, deserted the country. The depressed condition of the mining interests of the region, that naturally followed this revulsion of feeling, prevailed until the approach of the Pacific railroad gave a fresh impulse to those districts lying within its influence, when the influx of men into the country, the easy communication with the markets, and the cheapening of supplies brought about a more hopeful state of affairs. In the neighborhood of Unionville some degree of mining activity has been kept up from the outset, and it is there that the industry of the West Humboldt range is now chiefly centered; while, within a year or two, other districts in the same range, and in the ranges further east, have been attracting increased attention, and are growing steadily in importance.

For a more detailed description than will be given here of the several mining districts in this range and in Humboldt County generally, the reader is referred to the report of R. W. Raymond, esq., United States Commissioner of Mining Statistics, who has noticed the more important localities at considerable length. The writer will confine himself here to a few notes concerning some of the points that came under his personal observation.

The general geological structure of the West Humboldt range will be more particularly described in another volume of this report. The rocks are chiefly metamorphic, consisting of highly siliceous porphyry or quartzite,

broken through in central portions by granite, and flanked by massive beds of fossiliferous limestone, slates, and calcareous shales. These stratified or bedded rocks have a course generally east of north and west of south, dipping northwesterly at the northern, and southeasterly at the southern end of the range, the geological axis of upheaval not coinciding with the trend of the range. Veins of ore-bearing quartz occur in all of the metamorphic rocks, having variable course and dip, but those that have thus far appeared most important have been found in the limestones or bedded calcareous rocks, conformable with them in strike and dip.

The oldest mining district in the county was organized in 1860, on the west slope of this range, under the name of Humboldt District, a little north of Star Peak, the highest point in the range, and but a few miles from where the Pacific railroad now passes. It was actively prospected for a time, when, owing to general discouragements, all work was suspended, and, at the time of the writer's visit, nothing was in progress there. The eastern slope, on the opposite side of the range, has been the scene of much more enterprise in the development of the so-called Buena Vista, Star, and other districts. The first of these derives its name from Buena Vista cañon, in which the town of Unionville is located. This cañon, which, with its several branches in the higher portion of the range, is several miles in length, has been extensively prospected. Many veins have been opened, with more or less development, some of them, no doubt, having little or no value, others producing very good ore and possessing favorable indications of permanency. The most of them, however, the good as well as the bad, have suffered from the general depression, and, since 1865, have been awaiting the return of confidence and capital to proceed with their development.

The principal vein of this neighborhood, and the one on which mining operations have been prosecuted with the least interruption, is that known as the Manitiwoc and Arizona. The ground held under these claims has been persistently worked by Messrs. Fall and Temple, and, within a year or two past, their perseverance has been rewarded by very successful results. A portion of the property has been sold to the Silver Mining Company, and has also been developed to a considerable extent under the management of Mr. Samuel Stewart. These two companies work their ground at

present through one tunnel, and, in effect, as one and the same mine. The ledge, as it appears from the work already done upon it, is a seam or vein of quartz, from one to four feet thick, and sometimes thicker, inclosed in beds of calcareous shales or slates, that here form the crest of a ridge, which consists mainly of quartzite or porphyritic rock. The vein crops out along the hillside, and is apparently conformable with the bedding of the strata, which, in general, strike northeasterly or east of north, dipping flatly to the southeast; but the strike and dip of the rocks, at the point where the mine is opened, are very irregular, owing to disturbances or movements to which they have been subjected. Indeed the principal mining development of the ledge, visible in September, 1869, has been made near what appears to be the axis of a small synclinal fold in the beds, in which folding the vein or ledge takes part. One of the companies was then working on one side of the fold, its ore-bearing seam apparently striking north 30° west, true, and dipping south 30° west, at an angle of but few degrees near the surface, but increasing greatly in depth; while the other party was at work on the opposite side, where the strike of the seam was north 15° west, true, dipping easterly, or north 75° east, at an angle of 35°; that is, the ledge, in the two places referred to, showed two varying dips, in two nearly opposite and approaching directions.

The casings of the vein, or ore-bearing stratum, are, for the greater part, very distinct, and are usually accompanied by a "gouge" or selvage of clay. The filling of the vein is chiefly quartz, carrying, distributed through it, particles or bunches of rich mineral, consisting of black sulphuret of silver, argentiferous lead and copper ores, some chloride of silver, and native silver. Some of the ore is very rich, averaging by assay $400 or $500 per ton; the greater part of it has an assay value of $60 or $70 per ton. The average assay value of all the ore produced is stated at about $100 per ton.

The workings of the two companies extend over several hundred feet along the outcrop of the vein, and have penetrated the hill by tunnels over 400 feet in length. Each company was working vigorously in the autumn of 1869, when the mine was visited by the writer. About 45 or 50 men were employed altogether, being nearly equally divided between the two companies. Each company was then producing between 300 and 400 tons of ore

per month. This product is divided, by assortment, into two classes. The first consists of rich mineral, of which the average assay value is about $500 per ton. This is put up in sacks and shipped to San Francisco, where it is worked by some of the local metallurgical establishments, or sold for export to England. In either case the realized product amounts to about 80 per cent. of the assay value.

The second-class ore, having an average assay value of about $60 or $70 per ton, is worked in mills, near the mine, by crushing under stamps and amalgamation in pans. The proportion of first-class to second-class ore is said to be about one ton in twelve or fourteen. Thus, in the month of September, in which the average relation of the two classes is said to be fairly represented, the Silver Mining Company produced 300 tons of second-class, or crushing ore, and shipped to San Francisco 25 tons of first-class ore.

There are three mills in the neighborhood working on the ores produced from these mines. Two of them belong to Messrs. Fall and Temple, or the company represented by them; the other, to the Silver Mining Company. They are situated near the mouth of Buena Vista Cañon, in the foot-hills of the range, just below the town of Unionville, and a mile and a half or two miles from the mine. One of Fall and Temple's mills was built several years ago, and was in process of reconstruction when visited. It has a partly sufficient water-power; when rebuilt it will have ample steam-power, and be supplied with ten stamps of 650 pounds weight, two large Wheeler and Randall Excelsior pans, and one smaller Wheeler pan; besides the usual accompanying settlers, agitators, &c.

The new mill of Fall and Temple has ten stamps of 750 pounds weight, six pans, (four Varney and two Wheeler,) and three settlers, or separators. This mill is driven by steam. The Silver Mining Company's mill has five stamps of 650 pounds weight, two Wheeler and Randall Excelsior pans, one Horn pan, and two settlers, or separators. The stamps in this mill crush about 10 tons of ore per day, working the pulp in the Wheeler and Randall pans, and reserving the Horn pan for the treatment of tailings.

The ores in all these mills are worked in similar manner, the process generally resembling that in use at Washoe. They are crushed wet and amalgamated in pans without roasting. The ores, however, are not so docile

as those of the Comstock lode, and the method is consequently not so well adapted to their proper treatment. The yield from the first crushing and amalgamation is not believed to exceed 50 or, sometimes, 40 per cent. of the assay value; but the tailings are worked over, after standing a while, and a fair proportion of their value is extracted by a simple repetition of the pan process. The yield obtained from the raw ores during the past year has usually varied between $25 and $35 per ton; while the tailings, by reworking, yield from $20 to $30, and are even treated repeatedly with profitable results.

The steam-mills here use sage brush as fuel during the summer, and find it cheaper than cordwood. The latter costs $12 per cord in this neighborhood. Chinese labor is employed in the mills in every department of the work, excepting in driving the engines. The Chinamen give great satisfaction.

Detailed statements of the costs of mining and milling are not in possession of the writer. It is stated, however, that the product of the second-class ore by the first crushing and amalgamation is sufficient to pay all the costs of operation, leaving the first-class ore and tailings as profit. The Silver Mining Company, according to the statement of its manager, made a profit of $12,000 in the month of September, 1869. This latter company had been in producing condition but four or five months. Up to the 1st of October, 1869, the value of its bullion shipments, produced from second-class ores, amounted to $51,433 27; while the first-class ore shipped up to that date had given a net return of $27,352.

The shipments of first-class ore by Fall and Temple from April 1 to October, 1869, amounted to 89 tons, having an average assay value of $450, coin, and yielding a net return of 75 per cent. The bullion shipments derived from second-class ore amounted to about $150,000 in fourteen months, ending October 1, 1869.

The two companies whose operations have just been referred to have of late been the most productive in the county of Humboldt. In the summer of 1869 there was but little work in progress in the immediate vicinity of Unionville, except that which was connected with their mines and mills. There was, however, some activity in prospecting or developing other veins.

Just above the town of Unionville, on the north side of the cañon, the National Mining Company was at work upon a lode bearing the same name, which has been opened along the surface for a considerable length and prospected to a depth of about 100 feet. The vein is said to yield a rich gold-bearing quartz. A small mill of four stamps was in process of construction, and nearly ready for operation in September, but had not, when visited, begun to crush rock. Trials of the quartz from this vein, made in other mills, promised successful results.

Further up the cañon the Seminole Tunnel Company was engaged in driving an adit into the mountain, with the view of cutting a series of ledges that had been opened on the surface, with some indications of value.

West of Unionville, on the opposite or western slope of the range, there has been a large amount of prospecting work done in the various cañons, most of which was followed by discouraging results at the time of its performance, but which may yet be turned to good account under the increased advantages secured by the railroad. One enterprise of importance is the Alpha mine, in Panther, or Butte, Cañon. The ledge on which this mine is located has been in course of development for several years, though the force employed in the work was very small, at least until lately. It is now owned by the Nevada Land and Mining Company, and is being more vigorously worked. It is easily accessible from the railroad, by which means the higher grade ore is now shipped to Reno and roasted by the Stetefeldt furnace, and subsequently amalgamated in pans. The writer is not in possession of definite information concerning the average value of the ore or the extent of the operations of the present company.

Star District.—Directly north of Unionville, also on the eastern slope of the range, is the Star district, once the scene of very lively prospecting and busy enterprise, that was soon followed by utter abandonment of the region. Star Cañon has been explored from its mouth to the crest of the range, and many series of promising veins have been discovered. Among them is the celebrated Sheba mine, which made good its promise, it is said, to the extent of over \$125,000, a single pocket or bonanza having yielded \$75,000; but its visible resources having been exhausted without meeting the expectations of its speculative owners the work was suspended and has long been lying idle.

The rocks of the range cut through by this cañon consist of quartzite, limestone, shales, and slates, dipping with considerable uniformity to the westward, striking north and south or north a little easterly. Most of the important veins, though not without exceptions, conform with the country-rocks in course and dip. Such is the case with the Sheba vein just referred to, a deposit which lies between a black rock of slaty structure as a hanging wall, and a bluish, probably calcareous, bed below. In places the ore-bearing ground has a great width, it is said 150 feet; but as the mine was inaccessible to the writer, there was no opportunity to verify the statement.

The same vein on the south side of the cañon is known as the De Soto. On this property the vein has been explored by tunnel for a length of about 600 feet, and to a depth, at the inner end, of 300 feet below the surface. In general, the lode varies from two or three to five feet in width. The hanging wall is well defined, smooth, and regular, generally underlaid by a foot or more of soft, clayey material, talcose in appearance. The filling of the vein or ore-deposit is chiefly made up of bluish limestone, somewhat argillaceous in appearance, very fragmentary in character, having all the seams and interstices filled up by quartz. These quartz-seams are sometimes large and continuous for considerable distances. The ore is associated with this quartz, and consists chiefly of rich silver minerals, antimonial sulphurets, fahlerz, &c. Galena and zincblende are associated with the ores. The assay value of the assorted ore is very high. The ore occurs in bodies, chimneys or bonanzas, and the vein contains long intervals of barren ground. This feature partly explains the history of the Sheba, the mine having been very productive while in bonanza, which, being exhausted, the patience of the stockholders was not sufficient to search persistently for more.

The De Soto was first opened in 1861, since which time a considerable amount of work has been done upon it, but with long intervals of quiet. In the summer of 1867 five men were employed there, and the results of their labor were deemed very encouraging; but the work was soon after suspended, and, so far as the writer of this is informed, still remains so.

Star City, a town of considerable size and importance in the earlier days of its career, is situated in the neighborhood of these mines. It possesses a number of large buildings, stores, post office, express and telegraph stations.

One of its hotels is said to have cost $40,000. For the last few years the town has been almost entirely deserted. A mill of ten stamps and four reverberatory furnaces for roasting the ore was built long ago at the mouth of the cañon, but has lately been taken down and removed to Unionville, a portion of its material being used in reconstructing Mr. Fall's mill.

The next range of mountains occurring east of that in which Unionville is situated contains several districts, some of which have been extensively prospected, although not very persistently developed. The principal point of operations has been in the neighborhood of Dun Glen, a small town or mining camp seven miles from Mill City, and about 25 miles from Unionville. The most notable mine in this locality is the Tallulah, working on two or three veins, and producing ore that is reported as very rich. Other companies have also made developments that were regarded as very encouraging; but mining operations, during the last two or three years, have not been very actively prosecuted. In the summer of 1869 there were but few men at work in this region, though, later in the year, a mill, situated at Dun Glen and belonging to a New York company, resumed work, and a more vigorous development of the district was looked for.

Gold Run.—The Gold Run District lies upon the east side of the Golconda Mountains, the next range east of that last referred to. The center of operations is about 12 miles from the Pacific railroad. Its point of communication with that road—a station known as Golconda—is 341 miles from Sacramento. This region was visited, in 1868, by Mr. Arnold Hague, from whose notes the following brief statement is obtained.

The principal mines appear to be located upon one vein, occurring in a metamorphic, siliceous slate, which here forms the foot-hills of the mountain range. The vein strikes due north and south, and is said to have been traced for a distance of more than three miles, extending southerly from the Golconda mine to the Jefferson mine, where it is apparently divided, one branch striking southwest and the other southeast. The vein, in that part which is most developed, dips to the west at an angle of 30° degrees from the horizon. It is six or seven feet wide. At the time referred to the vein in the Golconda mine had been explored to the depth of 50 feet, and drifted upon, at that level, about 120 feet. So far as developed the vein appears to main-

tain uniformity in course, dip, and width, and in the character of its ore. The walls are well defined, and both foot and hanging walls are the same metamorphic slate. The ore is very much decomposed, and consists chiefly of oxidized products, containing a good deal of "base metal." The silver occurs in the form of sulphuret. The vein rock is cut by seams of soft, white, clayey material, which carries finely disseminated silver sulphurets.

The Golconda mine is one mile and a half north of the small town of Cumberland. A force of thirteen men was employed in this mine in the summer of 1868. The company have a mill situated seven and a half miles north of the mine, which is furnished with eight stamps, five Varney pans, and eight Knox pans, used as settlers. The mill was then working about 10 tons per day, of which the average yield was $35 per ton.

The other mines had been less developed than the Golconda. The more prominent of these were the Cumberland, Register, and Jefferson. The last named, at the south end of the vein, near the "split," has an incline, sunk to a depth of 65 feet on the vein. The mill assay of eight tons of ore from this claim gave $48 per ton.

Battle Mountain District.—This district, about 30 miles further east, is one that is rapidly growing in importance. It is south of the Humboldt River and near the railroad. The station of the same name, by which the mines of this region are made accessible from the road, is 379 miles from Sacramento. The district is about 12 miles long, in a north and south direction, by something less in width. It lies on the west side of Reese River Valley, and in the eastern foot-hills of the Battle Mountain range. The river bed here is dry during a portion of the year. The mountain streams, in the neighborhood of the mines, furnish water enough for mining, milling, and domestic purposes, and, in some cases, for driving power. There is a fair supply of wood and timber, suitable for fuel and for use in the mines, in portions of the district and in the adjacent country.

The principal mine in the neighborhood is the Little Giant, chiefly owned and worked by Mr. G. W. Fox. It is eight miles from the railroad station. The vein, on which this mine is opened, was first prospected in 1867, and was developed by a small force until May, 1868, when the work was prosecuted with greater vigor. During the following summer a five-

stamp mill was erected, which, in the autumn, began to crush ore, affording very satisfactory results to the owners of the mine.

The vein is inclosed in quartzite. It crops out and is opened upon or near the summit of Little Giant Hill. Its course is north 55° west, true, dipping to the southwest at an angle of 55°. It is from one to three feet wide, averaging about two feet. The gangue is chiefly quartz; this, when clear, is white and hard; but it is usually intimately mixed with the ore, which, being decomposed, imparts to the whole mass a dull yellow color and a soft, crumbly texture. The ores near the surface are, apparently, much oxidized, the products of the decomposition of other sulphureted combinations of silver, associated, doubtless, with lead, antimony, and other base metals. In depth the ore is less changed, showing sulphureted and antimonial forms of silver-bearing minerals, which make their metallurgical treatment more difficult.

On the western slope the vein has been opened on the surface, 300 or 400 feet below the crest of the hill, and thence upward it has been stripped along its outcrop entirely across the summit of the hill and down on the eastern slope at frequent intervals. The length of Mr. Fox's claim is 1,400 feet, of which some 400 feet have been developed by means of three tunnels or adits. The upper tunnel, 130 feet long, is driven in on the vein from a point about 60 feet below the top of the hill; the second, 60 feet lower, measured on the incline of the vein, is about 100 feet long, and the third, 150 feet lower, is 230 feet long. All of these tunnels have shown a good vein, regular in course and dip, and generally productive of good ore. Some of the ground has been stoped out, though by far the greater portion opened by this work was still available for future operations when visited in September, 1869.

A portion of the ore produced, especially from the upper levels, was of a docile character, easily worked by pan amalgamation, although leaving rich tailings; while the other portion, less affected by the oxidizing influences of the surface, remained unworked, and ready for shipment or treatment by some other process. There were on hand, at the time above referred to, about 100 tons of ore of this class, of which the assay value varied between $100 and $1,000 per ton, averaging about $300. The ore selected for milling is said to yield, on the average, $150 per ton, sometimes reaching a much

higher figure. The tailings assay about $50 per ton. The mill, which is placed near the mouth of the cañon, a mile and a half below the mine, contains five stamps, each weighing 700 pounds, capable of crushing about 10 tons per day in the aggregate. There are two Wheeler pans, working on freshly crushed ore, and one Horn pan, working on tailings. Ten men are employed in the mine, and eight in the mill. Labor costs $4 per day. The product of the mine, up to July 1, 1869, according to the returns of the county assessor, which include nothing for first-class ore awaiting treatment, nor anything derived from the working of tailings, amounted to nearly $70,000.

The Little Giant vein has been traced, in both directions, beyond the claim of Mr. Fox, and there are locations made upon it by other parties, none of which, however, have yet been extensively developed. There are, also, other veins in the immediate vicinity, which have been somewhat prospected, with encouraging results, having, it is said, much similarity, in general features, to the one just described.

The southern part of the district, about eight miles from the Little Giant, has lately been the scene of active operations, chiefly in the development of copper-bearing ores, but also in the discovery and prospecting of veins that are rich in silver, and generally resemble the Little Giant in the character of their ores. The veins of copper have been known several years, but have only of late been regarded as very valuable. The copper occurs in the form of black and red oxide, with which is associated some native metal. It is found in ledges that are from two to six feet wide, and show strong indications of permanency. The ore assays very high in metal, and is said to yield 40 per cent. in large quantities. Shipments of ore were made during the autumn to San Francisco, where it was purchased for export to England. The property is reported to have been sold lately at a large price; and, according to newspaper report, is now undergoing vigorous development with very satisfactory results.

At Duck Creek a vein has been opened, resembling, in many respects, the Little Giant. Trials of the ore had been made at Fox's Mill, with encouraging results, and development of the property was in progress at the time of the writer's visit.

# SECTION II.

## GEOLOGY OF THE TOYABE RANGE.

BY S. F. EMMONS.

General Features.—The name Toyabe, which signifies in the Indian language "mountains," has been appropriately applied to this great range, whose sharp, serrated ridge rises several thousand feet above the neighboring ranges which rib the surface of the great Nevada plateau. The view from its summits extends over more than four degrees of longitude, and is limited only by the White Pine and East Humboldt Mountains on the east and the Sierra Nevadas on the west, whose forms and outlines can be traced with the utmost distinctness in the dry, thin air of these elevated regions. Snow rests upon its higher points until late in the summer, and, with the verdure which accompanies it, forms a most pleasing contrast to the somber hues that prevail over the mountains of this arid region. Rising nearly 6,000 feet above the broad valleys which border it on either side, its height is rendered still more imposing by its limited lateral extent, its average width from foot to foot being scarcely eight miles in a horizontal line; contrasted with the steep slopes of its sides, the valleys, although very considerably inclined toward their center, seem almost level ground.

The present geological sketch and accompanying map, the result of four weeks' explorations, cover an extent of nearly 60 miles in the direction of the range, including thus its most characteristic portion as an independent and isolated ridge, embracing as well those parts in which any important mining developments have been made. Beyond the limits of the map it spreads out laterally, developing a system of cross-ridges, which, connecting it with the neighboring ranges, form respectively the northern limit of Smoky Valley, which borders it on the east, and the southern water-shed of Reese River Valley, which drains its western slopes.

This portion of the range has a trend of about north 23° east, and, in general outline, forms a high single ridge, characterized by a short, steep declivity on the east, and a longer and more gentle slope to the west; but a

closer examination of its topography discloses a double ridge system, which prevails through the greater part of its extent, giving rise to a series of interior longitudinal basins; hence the line of the main water-shed is extremely sinuous, although that of north 23° east would pass through all the principal summits of the range. To the north the range consists of two low and somewhat broken diverging ridges, inclosing between them the Park basin, which opens out further north into the large meridional depression called Grass Valley. These ridges rise gradually to the south, preserving a certain parallelism, though broken through at various points by the waters of the high, narrow valleys which they inclose, until they reach their culminating points, respectively, in Bunker Hill and Big Creek Peaks. In this extent, although the eastern ridge is generally over a thousand feet higher than the western, the greater part of their surface is drained into Smoky Valley through Park Creek, Birch Creek, and Kingston Creek, which break through the eastern ridge, while only Big Creek flows to the west. For a few miles south of Big Creek Peak, the western ridge forms the main divide of the range, which bends round the head of Kingston Creek, but to the south of it forms a continuation of the main eastern ridge. For a distance of 25 miles south, the range consists of a single and, in general direction, straight ridge, with steep, craggy slopes to the east, and long, smooth western spurs. By the bend in this ridge to the westward at Summit Cañon, the western summit again becomes the main divide, its continuation to the north being indicated by the widening of the spurs toward the west, which inclose the small basins at the heads of Cross's and Washington Cañons. This ridge grows higher toward the south, till in the sharp peak of Mount Poston it forms the highest crest of the range. The eastern ridge, meanwhile, finds its continuation in the shoulders of the eastern spurs, which, rising into high peaks at the Twin Rivers, inclose the large interior basins of these cañons, around whose head the main divide makes another bend to the eastward. These numerous mountain valleys afford most excellent summer grazing ground, their slopes being covered with bunch grass, which remains green and nutritious long after that of the plains is parched and worthless; they form, moreover, natural inclosures, where cattle can be left comparatively unwatched, without danger of their straying.

The steep, sheltered sides of many of the cañons of the range support a growth of piñon and juniper trees, with some yellow pine, fir, and mountain mahogany, which, though somewhat sparse, is abundant compared to the average mountain range of this region, and sufficient to afford several years' supply of mining timber and fuel to mines that are likely to be opened.

The agricultural resources of the range are not sufficient to support its present limited population, being principally confined to the more hardy vegetables, which have been successfully cultivated in some of the larger cañons; fair crops of grain have, however, been raised on the bottom lands at the mouths of Big Creek and Kingston Cañons, and along the borders of Reese River and of the Smoky Valley Flat, when the supply of water has been sufficient and the slope of the ground suitable for irrigation.

The valleys which border the range on the east and west are broad, plain-like depressions, from six to twelve miles wide, their sides sloping up toward the foot-hills of the mountains, which are from 600 to 1,200 feet above their lowest point. Their surface is covered by a scanty growth of sage brush, which, in their lower and more moist portions, is replaced by a coarse wire or swamp grass. That on the west is traversed by the Reese River, which flows northward into the Humboldt, of which it is the longest affluent; but, although opposite Austin it is a considerable stream, with an average fall of 25 feet in the mile, it seldom reaches that river, owing to the great evaporating power of the atmosphere.

Smoky Valley, on the east, is both deeper and wider than Reese River Valley, and forms an independent basin; the waters flowing into it from this range all drain toward a large mud or alkali flat, opposite Park Cañon, which is about 18 miles long by 6 miles wide; a low divide, opposite the Hot Springs, forms the southern limit of this basin, though the valley extends over a hundred miles further south without any considerable change of level. Such alkali flats as this form a very characteristic feature in the scenery of the great plateau; partially covered by water from the melting of the snows in spring and early summer, its surface, destitute of all vegetation, is left, by the evaporation of these waters, incrusted with a thin, white coating of mineral salts. At its northern extremity is the so-called salt marsh, where these incrustations are so considerable that large quantities of the salts (here con-

taining from 50 to 60 per cent. of chloride of sodium) are collected for use in the reduction works in the vicinity. It is probable that saline springs exist under this portion of the flat, as the salts which have been removed are constantly replaced by fresh incrustations.

The hot springs in the southern portion of the valley do not differ essentially from others in the State, which are of frequent occurrence in the vicinity of large masses of volcanic rocks. They are a group of circular-shaped pools, from one to thirty feet in diameter, in a slight elevation, formed by the deposit from their waters, on the edge of the wash from the hills; they vary in temperature from that of the air to the boiling point; their supply of water but little more than compensates for the evaporation of the air, and streams run from them but for a short distance. The most interesting of the group is one shaped like a bowl, about three feet in diameter and as many deep, from the center of which the steam issues with such force as to throw up the water in a little jet, a foot or more above the surface of the pool. These springs are used both for bathing and cooking purposes; their mineral character has not yet been determined.

ROCKS.—The rocks of this range may be divided into three general classes: the sedimentary formations, the ancient eruptive rocks or granites, and the recent eruptive or volcanic rocks. These three classes represent in age the three geological periods—Paleozoic, Secondary, and Tertiary.

*Sedimentary rocks.*—On the accompanying map the colors of the carboniferous formation have been provisorily assigned to all the sedimentary rocks of this range, inasmuch as the only fossil remains as yet discovered here belong to that period.

*Limestone.*—The limestone bodies consist of a compact, dark-blue rock, in general, probably somewhat metamorphosed, fine-grained to granular, and frequently intersected by small seams of white crystalline calcspar. The only characteristic and well-defined fossil found by the writer in the somewhat limited time of his researches is the *Fusilina cylindrica*, which is generally assigned to the lower carboniferous limestone; besides this were a float fragment of siliceous limestone, containing *Syringopora*, and some molds of shells too much metamorphosed to be recognized. These limestones are found on the flanks of the range, resting conformably on the slates.

*Slates.*—In the slates are comprised the more highly metamorphosed beds, which include fissile limestone shales, more or less siliceous clay-slates, and, locally, schistose and somewhat crystalline rocks, resembling mica and hornblende schists, and, in one instance, a marbleized limestone. As these rocks form a gradation into the limestone, their line of division cannot always be definitely located. These beds have been so much disturbed and contorted, and their character so frequently changed by local metamorphism, that it has been impossible for the writer to form a satisfactory estimate of their thickness; probably 7,000 feet would cover that of the slates and limestones combined.

*Quartzites.*—The quartzite series, found only in the southern portion of the range, form beds of compact white quartz rock, colored reddish-brown on the weathered surface, between which are intercalated thin beds of white granular limestone. These are found underlying the slates, with no apparent nonconformity; they represent a thickness of several thousand feet, and may belong to the Devonian series; this point will probably be elucidated by the future work of this survey, when the character and thickness of the strata which make up the carboniferous and lower formations in this region will be definitely determined.

*Granites.*—The only considerable bodies of the older eruptive rocks in the range are the granites, which form intrusive masses, upon which rest the sedimentary rocks. They vary in texture and composition, to a certain degree, in the different bodies, but are generally characterized by a large proportion of quartz and an almost entire absence of hornblende; the proportion of mica entering into their composition is generally small, and, in one body, replaced by chlorite, forming a protogine-granite.

A series of syenite and greenstone dikes, often so fine-grained and compact that their composition could not be determined, which occur with remarkable frequency and regularity along the eastern slopes of the range, cutting through the granite as well as the various sedimentary formations, may be considered to form a second phase of the granitic eruption; these dikes, though from 20 to 50 feet wide, were too small to be represented on the map.

A body of dioritic rock, occurring at the Twin Rivers, supposed to be

the product of a later metamorphism, has also been left undesignated by any distinctive color.

*Volcanic rocks.*—These rocks are not known to occur earlier than the tertiary period; those found in this range may be referred to the two varieties, propylite, the earliest of the volcanic series, and rhyolite, generally considered to be among the most recent, though here it has directly succeeded the propylite. Both of these rocks have played an exceptionally important part in the structure of this range, since they usually occupy orographically a subordinate position.

*Propylite.*—Both hornblendic and quartzose varieties of propylite are found in each of the two localities of this rock in the range, but, compared with other bodies in the State, they are very rich in silica.

*Rhyolite.*—This rock, usually noted for its great variety of texture and color, though it occurs here in exceptionally large masses, is of comparatively uniform texture; it is generally of the crystalline or granitic variety, the occurrence of the porphyritic, hyaline, and earthy texture being of subordinate importance.

The quaternary formations are represented by the extensive accumulations of detrital material, which cover the sloping sides of the adjoining valleys, varying from a coarse gravel, inclosing occasional large rock fragments, to a fine, almost impalpable, silt. The gravel benches of the park basin may be referred to the same period.

STRUCTURE OF THE RANGE.—The geological formation of this range, presenting as it does the result of upheavals, metamorphisms, and eruptions, extending over long geological periods, affords the type of a most complicated mountain structure, of which the present report can only claim to give the general outlines.

In its original elevation, as represented on the map by the stratified rocks and granites, may be traced the result of the action of forces of contraction or compression, acting in two directions, laterally, or at right angles to the general line of elevation, and longitudinally, or parallel to that line. The lateral, or main forces of upheaval, have produced anticlinal and synclinal folds, whose axes would have the general direction of the range. The effect of the longitudinal compressions has been a disturbance of these conditions, causing a deviation from the general direction, and a crumpling and

general dislocation of the strata, in those parts where the fractures produced by the first-named forces have not been filled by the intrusion of granite bodies, thus offering a greater resistance to the disturbing forces.

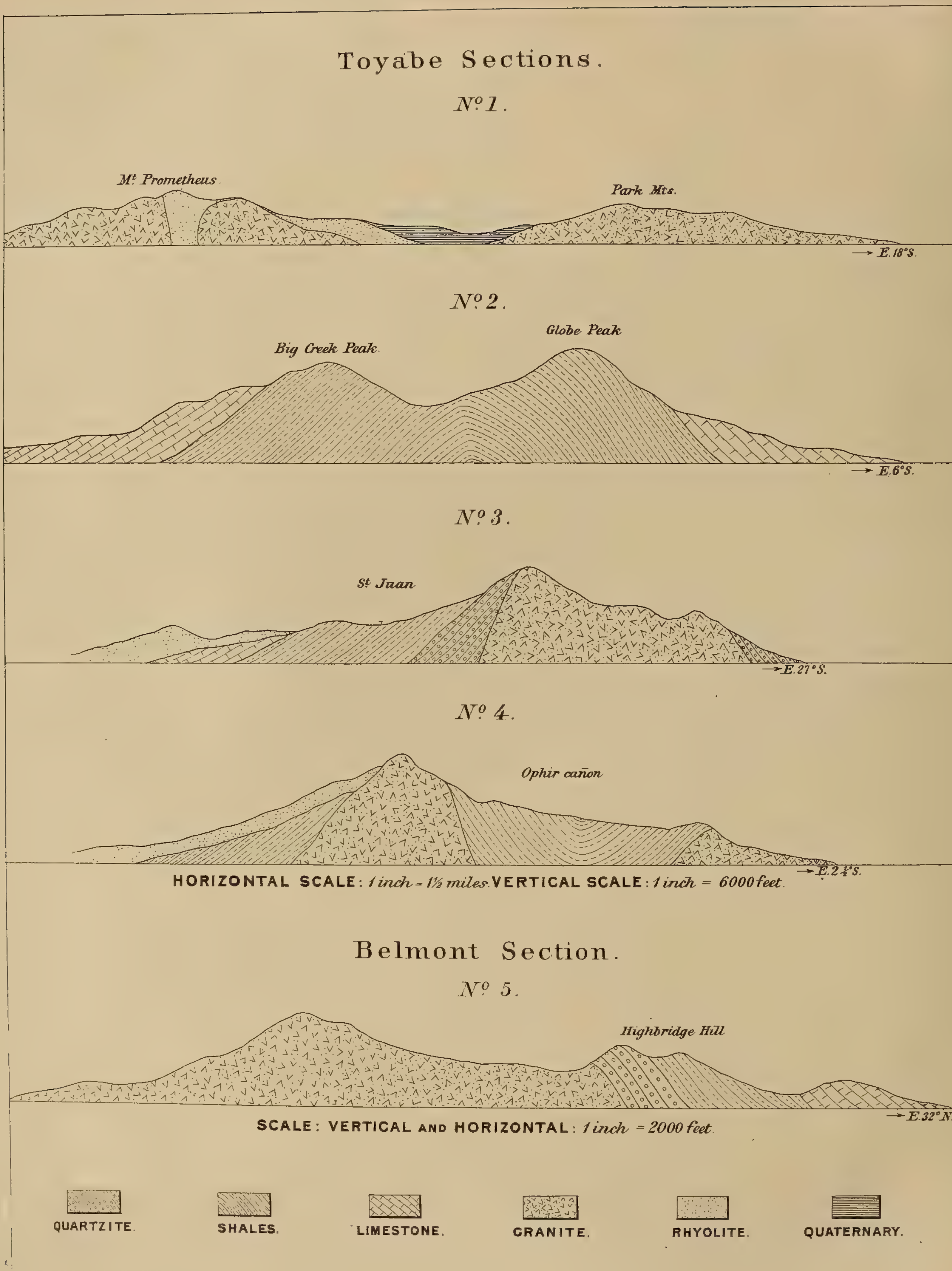
By reference to the map, Atlas-Plate 13, it will be seen that there are five principal bodies of granite—two northern, those of Austin and Geneva; two southern, the eastern and western Ophir Cañon bodies, and a long intermediate or central body. The Geneva and central and eastern Ophir Cañon bodies seem to belong to one line of upheaval, while the Austin and western Ophir Cañon bodies represent independent lines of elevation.

The central mass of sedimentary rocks, comprising the double ridge system of Globe, Bunker Hill, and Big Creek Peaks, included between the Geneva and central bodies of granite, forms a general anticlinal fold, whose ends overlap respectively the extremities of those bodies; here the effect of the longitudinal compression is most distinctly seen, since the axis of the fold has an extreme variation in direction from about north 35° east, on the northern end, to north 20° west on the southern, with an intermediate re-entering angle to the east.

On the north the appearance of the Austin granite seems to have been accompanied by an upheaval of the metamorphic slates of Telegraph Peak to the north, and of the slates and limestones to the south, forming a partial synclinal with the western member of the main anticlinal fold where it rests on the Geneva body of granite.

The position of the stratified rocks in the portion of the range south of Kingston Cañon seems to be mainly due to their upheaval in the line of the granite bodies, which form two generally parallel lines of elevation, represented by the central and western Ophir Cañon bodies.

The elevation of the central granite body represents in the main a monoclinal uplift, though isolated bodies of metamorphic rock occur on the eastern flanks of this body, whose relations have not been accurately determined. By the continuation of this line of upheaval to the south, in the eastern Ophir Cañon body, which is a metamorphic granite, a synclinal fold in the strata is formed between this and the western granite; the western uplift probably extends for some distance north of this body to the limestone on the flanks of the monoclinal.


Toyabe Sections.
No. 1.
Mt. Prometheus.
Park Mts.
→ E. 18° S.
No. 2.
Big Creek Peak.
Globe Peak
→ E. 6° S.
No. 3.
St. Juan
→ E. 27° S.
No. 4.
Ophir cañon
→ E. 2¼° S.
HORIZONTAL SCALE: 1 inch = 1½ miles. VERTICAL SCALE: 1 inch = 6000 feet.
Belmont Section.
No. 5.
Highbridge Hill
→ E. 32° N.
SCALE: VERTICAL AND HORIZONTAL: 1 inch = 2000 feet.
QUARTZITE.
SHALES.
LIMESTONE.
GRANITE.
RHYOLITE.
QUATERNARY.

To subsequent metamorphic or eruptive action is probably due the formation of the numerous veins and dikes which intersect the original formations. The intensity of metamorphic action has increased toward the south, as seen in the metamorphic granite at Ophir Cañon, and the partially crystalline slates, which, at the Twin River, are replaced by metamorphic diorites. There are also evidences of later dynamic action, whose extent cannot be determined.

In the volcanic period the appearance of the propylite bodies of the Point of Rocks was accompanied by considerable disturbance of the adjoining rocks, which now seem to rest upon it, and to be somewhat altered at the contact; this action was apparently more extensive to the south than to the north of this body. The southern eruption of propylite seems to form a continuation of the western Ophir Cañon body of granite to the south, covering the present bed of the Twin River basins, and to have been accompanied by extensive metamorphic action on the rocks to the east of it.

The rhyolite eruptions have not in general been accompanied by any considerable disturbance or alteration of the adjoining rocks. Those of Mount Poston, and the peaks above the Hot Springs, have overflowed the propylite and, probably, the slates of the western slopes of the range; it is not certainly known whether the San Juan rhyolite is part of this flow or an independent eruption; the indications of a lateral fold in the strata here would favor the latter supposition. The rhyolites at the mouths of Big Creek and Kingston are small isolated outflows, which have apparently had no action upon the adjoining rocks. The Mount Prometheus rhyolite has broken through granite, overflowing its flanks and those of the slates which rest upon it.

The sections given on Plate XXVI, which present approximate profiles of the range at different points, will serve to illustrate the idea intended to be conveyed in the above description.

No. 1, on a line drawn through Mount Prometheus, east 13° south, shows the relations of the granite and rhyolite bodies at that point.

No. 2, on a line drawn through Globe and Big Creek Peaks, east 6° south, shows the main anticlinal fold, though it cannot serve for an accurate representation of the thickness of the strata, since their strikes vary so much that it is impossible to choose a line which shall cut them at right angles.

No. 3, on a line drawn through San Juan, east 27° south, shows a section of the central granite body, the slates and quartzite resting upon it, and the rhyolite on their flanks.

No. 4, on a line, north 2½° south, drawn through the northern spur of Ophir Cañon, shows the two granite bodies, the synclinal fold in the slates, and the rhyolite flow from Prometheus which covers the western slopes.

To what extent the present configuration of the range is due to glacial action is not easy to determine, since the decomposable nature of some of the rocks, and the position of the strata of others, are not adapted to preserve the traces of such action.

From the fact, however, of glacier polishings having been found on the face of a spur, at the mouth of Santa Fé Cañon, in such a position as to necessitate the supposition of the existence of a glacier in that cañon, whose lower extremity, covering the end of this spur, extended out into Smoky Valley, it may be inferred that the basin-shaped heads of most of the large cañons were formerly filled by glaciers, which, flowing over the inclosing ridges at their lowest points, by their abrasion, followed the course of the present cañons; the subsequent action of water having cut the narrow gorges which now exist in their lower portions.

The great accumulations of debris at the mouths of the larger cañons, whose slope is frequently more than 6°, through which the waters have cut channels from 50 to 100 feet deep, and of more than double the width, favor this supposition, while the narrowness and steepness of the range, and the probable existence of lakes which filled the adjoining valleys, might account for the absence of any well-defined moraines.

The Austin body of granite, which is particularly interesting as being the principal ore-bearing body of the range, forms the core of the main ridge of the Toyabe, which is here comparatively low, for five miles south of Telegraph Pass. It is exposed mainly on the western slope of this ridge, where it is worn into the rounded spurs and open, shallow ravines, characteristic of an easily decomposed granite. This is a normal granite, consisting of quartz, feldspar, and mica; the feldspar of two varieties, a semi-translucent orthoclase, and an opaque white variety, probably oligoclase; the mica a dark magnesian variety; hornblende is found as an accessory ingredient, sometimes con-

centrated in bands or bunches. It forms the southern foot-hills of Telegraph Peak, underlying the metamorphic rocks, which are dark-blue siliceous limestone-shales, dipping to the north and east at a low angle. At Telegraph Pass it is exposed on the eastern slope of the ridge, where it is traversed by a dike, about 15 feet wide, of white granulitic rock, containing sparse crystals of mica, and black crystalline grains, probably of tourmaline, concentrated in bunches throughout the mass; this dike has a northwest strike, which is the direction of the principal veins of this neighborhood. Granite forms the crest of the ridge, as far south as Mount Prometheus. This peak is chiefly conspicuous as forming the summit of Lander Hill, the spur in which have been found the richest veins of the district; its summit, and the flat-topped ridge at the head of Marshall's Cañon, are formed of rhyolite, which covers the eastern slopes of the ridge, and forms the head of the Park basin; while, on the main ridge south of Marshall's Cañon, are found the dark metamorphic slates of Telegraph Peak, dipping southeast at a low angle with a northeast strike, and separating the granite, on which they rest, from the rhyolite, which forms the saddle connecting this ridge with the hills north of Geneva. The rhyolite of Mount Prometheus is not a very characteristic variety, inasmuch as it contains but little free quartz, while that of the Marshall's Cañon ridge is very like a trachyte, or, in some respects, an older porphyry; but their mode of occurrence, geological relations, and certain mineralogical characteristics favor the assignment to them of a rhyolitic rather than a trachytic origin, while their resemblance to the older porphyries is confined to the compact matrix of a limited local occurrence.

The mass of Prometheus and its eastern slopes are composed of a brownish-purple vesicular rock, in which a microcrystalline feldspathic paste incloses crystals of glassy feldspar, magnesian mica in large quantities, and occasional grains of smoky quartz; largely disseminated throughout the mass, and lining the cavities, which are frequently as much as an inch in diameter, are spherulitic concretions of feldspar, whose occurrence is generally considered to be characteristic of rhyolitic rocks. On the western crest of Prometheus, toward the main granite body, this rock passes into a black pearlite, in which the spherulitic structure is still found, though not so prominently developed as in the former, nor with the same concentric structure. The vitreous paste

incloses crystals of white sanidin feldspar and black mica, but apparently no free quartz; it has a dark, glazed, weathered surface, and frequently a columnar structure, forming small pentagonal and hexagonal prisms. The line of contact of this rock with the granite, which has a north and south direction, is marked by a depression in the crest of the ridge west of Prometheus, and a ravine on either side, showing that the granite was decomposed, and hence more deeply eroded on this line; and the pearlitic texture would seem to be due to the reciprocal action of the granite on the rhyolite body. The main rhyolite of Prometheus is also very easily decomposed by atmospheric agents; hence, in the low saddle of the main ridge above Austin and in various depressions of the eastern spurs, it has been eroded off, and the underlying granite laid bare; here the granite is found to be so thoroughly decomposed on the surface that it crumbles into fine quartz sand at the touch, the feldspar having been kaolinized, and the mica only leaving its traces in stains of iron oxide through the mass. In several places on the eastern slopes, however, the granite is found in large rounded blocks, in a comparatively undecomposed state; these may not have been entirely covered by the flow of rhyolite, or their outer decomposed surfaces may have been entirely worn away by the action of erosion, and the undecomposed kernel left as now found.

South of the pass above Austin extends a flat-topped ridge, having a gentle slope to the eastward, which is formed of a reddish-brown porphyritic rhyolite; its compact, homogeneous, feldspathic matrix incloses small crystals of sanidin feldspar, with no free quartz as far as can be seen by a simple *loupe;* in the valley to the east this rock is found, having a lighter drab-colored matrix, inclosing, in addition to the feldspar, crystals of black mica.

Still further south, on the divide which connects this ridge with the hills north of Geneva, and in a line due south from Prometheus, occur similar rocks, and in the same relative position as on that peak; they are, however, more compact, and have not the spherulites which are found in those rocks. Still another variety of texture is found on the eastern limits of the body; as these, however, are, in a great measure, covered by the debris of the Park basin, they are not so clearly defined as the western limits. On the northern slopes of the hills, north of Geneva and near the Overland Stage road, is found a brick-red rhyolite, having an earthy homogeneous texture, probably the

result of solfataric action. At the foot of a northeastern spur of Prometheus, on the western edge of the basin, is found another partially decomposed variety, of white color, having small crystals of quartz disseminated through the feldspathic matrix.

The line of fissure of this rhyolite eruption, as has been seen, is about north and south; the southern portion of the body, or that which occurs in the slates, has a different character from the rock of Prometheus, which has broken through the granite, and is, by the occurrence of granite on the pass above Austin, isolated from the rest. There is no evidence to show that these rocks are cotemporaneous or the reverse, since they are not found in contact on the surface; whatever the origin of the more southern rocks, however, the summit of Prometheus evidently marks the vent through which the rocks, composing its slopes, have come to the surface.

The most productive veins in the district occur on the south slope of Lander Hill, the granite spur, which extends to the westward from Mount Prometheus; of those most extensively explored the majority have a northwest strike, and dip at a low angle into the hill to the northeast. In these veins has been found a system of fractures or faulting, in a north and south direction, occurring with such regularity and persistence as to suggest the idea that the surface of the spur has experienced a general downward movement to the westward, or, what seems more probable, that the interior core of the spur has been uplifted in the opposite direction, possibly at the time of the rhyolitic eruption of Mount Prometheus, the line of movement being generally parallel to this fissure.

In the upper part of Marshall's Cañon, forming a dike in the granite, is a dark-green, fine-grained rock, impregnated with iron pyrites, which resembles a syenite, though its grain is too close to determine with accuracy its mineralogical composition. To the south the granite body gradually grows narrower, and in Ely's Cañon, the fourth south from Austin, is no longer seen. Here are limestone-shales, generally dipping south and east, though their strikes seem to vary a good deal. In the next cañon south is the commencement of a body of blue limestone, which extends south as far as Big Creek, and seems to be the least altered of any in the range. In it were found a few indistinct molds of fossils, but it is generally rather granular and crossed by small

seams of calcspar and quartz; the lime made from it in a limekiln, a few miles north of Big Creek, is said to be of very poor quality. The general strike of the body is north 35° east with a dip of 40° to the west, though the northern end apparently partakes of the construction of the slates resting on the Austin granite. An immense seam or dike of quartz is found near the summit of the ridge, above the limekiln, having a strike parallel to the general direction of the ridge, and corresponding in position to a quartzite dike near the head of Ely's Cañon. The occurrence of such dikes with a probable continuity for a long distance is one of the peculiar features in the geology of the range.

Directly east of Austin, forming the eastern water-shed of the Park Basin, is a group of conical granite hills, having three principal peaks rising about 1,800 feet above the neighboring valley, called the Park Mountains. Their entire mass appears to be of granite, which is in the main a compact, close-grained variety, in which the feldspars predominate; these are of two varieties, a flesh-colored orthoclase and a greenish-white, probably oligoclase, besides which the granite contains quartz and a magnesia mica, with some small green crystals, probably hornblende. A narrow dike is observable on the slope toward Park Creek, having a northwest trend, corresponding to that on the east of Telegraph Pass; the rock of this dike is a white granulite, containing no mica, and the feldspar seeming partially kaolinized.

On the north of the group the waters of the Park Basin have broken through the granite body in a narrow gorge, in which the rock has been very much decomposed by atmospheric agents, causing considerable accumulations of granite sands in the ravines. The granite extends into the hills north of this ravine for a short distance, and is succeeded by siliceous metamorphic slates which rest upon it, dipping to the northward. The extensive flows of rhyolite which form the table-topped ridges to the north and east, beyond the limits of the map, probably extend to the flanks of these slates.

Of the group of hills next south, lying to the north of Geneva, the highest point, which rises about 3,000 feet above the valley, is of dark metamorphic slates similar to those of Telegraph Peak, succeeded to the north by various fissile slates, whose debris form smooth slopes to the north and west. These slates have a general strike somewhat east of north, and are traversed

by several quartz veins, and some dikes of a light-colored breccia matter, having a northwest direction; the latter may have the same origin as the rhyolite, which forms the saddle connecting these hills with the Western or Austin ridge. On the eastern slopes the granite forms more jagged spurs, which are covered with a considerable growth of juniper, while the extreme eastern foot-hills are so covered with debris that the underlying rocks are not apparent. Geneva, or Birch Creek, Cañon presents a fine section of this body of granite; it is a narrow gorge, worn by the action of the water, in a generally straight course, though zigzagging in detail owing to the unequal resistance offered by different parts of the granite to the action of erosion; the walls rise very steeply on either side from 1,000 to 2,000 feet. The western part of the body is a very interesting variety of the so-called giant granite, composed of a mass of large crystals of orthoclase from one to two inches long, and rounded grains of quartz filling up the interstices of, and frequently inclosed within, these crystals; the mica, which is of the white potash variety, occurs in thin sheets between the crystals of feldspar. The general body of the granite is a white mass of quartz and feldspar, in which large crystals of orthoclase are porphyritically imbedded; small crystals of green magnesia mica and a little white potash mica are generally distributed throughout the rock. As exposed in the Commercial Company's tunnel, however, the mica is replaced by a light green mineral resembling chlorite. This tunnel has been cut over 800 feet into the granite spur to the south from near the mouth of the cañon, for the purpose of reaching the Big Smoky vein, which crops out about two hundred feet above it on the ridge of the spur, of which it has the general direction. The workings on this vein disclose a large irregular body of quartz and calcspar from 15 to 20 feet thick, stained by graphite; it would seem to be at the contact of the slates and granite, since these rocks are cut in alternate bands by the tunnel which reaches it from the south.

A noticeable feature of the granite exposed in this gorge is the regular bedding of the mass, amounting almost to a stratification, having a gentle dip to the westward; it may be estimated that a thickness of over 3,000 feet of granite is exposed here.

About half-way up the cañon the granite is traversed by a dike about 25 feet thick of close-grained greenstone, having a northeast and southwest strike,

and a dip of about 30° to the northwest. Above the granite the gorge spreads out into an open longitudinal valley, in whose bottom are exposed the upturned edges of the metamorphic strata, which rest on the granite.

South of Geneva Cañon commences the main high ridge of the Toyabe Range, which rises suddenly in Geneva Peak to a height of 5,400 feet above the valley. The granite forms only the northern point of this ridge, extending along under its eastern edge, while the summit is formed of slates resting upon it. Geneva Peak consists of limestone shales, striking a little east of north and dipping south at a low angle. From here south as far as Bunker Hill, the main crest of the range is a high sharp ridge of various argillaceous and limestone shales, whose dip changes to the eastward a short distance south of Geneva Peak. The western slopes toward the interior valleys are generally quite abrupt, though owing to the fragile character of the rocks they are so covered with debris and soil that the details of structure are not very apparent.

On the eastern foot-hills the slates come in south of Geneva Cañon, having a northeast strike, and dip to the east and south, resting on the granite, and extending higher up into the range as one goes south; these are overtopped by a body of limestone, which first makes its appearance at Tar Creek, and is found in varying thickness along the eastern flanks of the range as far as Kingston. This limestone is a dark-blue, semi-crystalline mass, more or less metamorphosed throughout, and in many places assuming a foliated structure, so that it is difficult to determine the line of division between it and the slates. While the main ridge forms the eastern edge of the general anticlinal fold, there seems to have been a lateral fold between Globe Cañon and Santa Fé, and the strata are found to be much contorted and disturbed in this region. Near the mouth of Globe Cañon the limestone strata have a quite regular dip of 40° to the east, on the north side, striking north and south, those on the south side being irregular and much contorted, while still further south in Santa Fé they are tilted up at a generally steeper angle and have various strikes. On the eastern slope of Globe Peak, which attains the already very considerable height of 11,237 feet above sea level, are a succession of fissile slates of various green and purple shades, including a variety of quartzose mica-schist, containing, however, but a small proportion of mica, which un-

derlie and are conformable with the limestones that form the eastern extremity of the slope. Both slates and limestones are traversed by numerous veins of quartz, some of which show good bodies of galena; these veins have a north and south strike generally conformable with the stratification.

On the lower face of the foot-hills, just north of the mouth of Santa Fé Cañon, are the remarkable glacier polishings already mentioned. A thin seam of gray quartz, striking north 15° east, with a dip of 59° east, here forms the face of the spur; its somewhat undulating surface has, on the salient parts, over a tolerably continuous extent of several hundred feet, received a mirror-like polish, equal to the finest produced by artificial means, so that when the sun's rays strike upon it at the proper angle their reflection is visible as a bright point from a distance of many miles. The lines of striation, which are only visible on a close examination, are parallel to the line of greatest inclination. The surrounding rock, which is a somewhat metamorphosed and slaty limestone, has not been of sufficient hardness to retain any other traces of glaciers, though it is evident that to this agency must be attributed these polishings. Their position is indeed singular, at the foot of such a steep slope, and entirely on the outside of the cañon basin; the head of this cañon, which extends up to the northeastern crest of Bunker Hill, must have been filled by a glacier, whose lower end overlapped this spur, which closes up, in a measure, the mouth of the cañon, and the descending mass of ice and gravel has worn away the less resisting rocks, while this sheet of quartz received its present high polish. As far as known this is the only instance of such ice polishings in the range, though, as elsewhere remarked, the shape of the interior valleys seems to indicate that they were once filled by glaciers. In the limestones of Santa Fé Cañon were found the *fusilinae* already mentioned. Near the mouth of the cañon is a dike of dark green, fine-grained syenite, consisting of hornblende and white feldspar, the former occasionally in columnar crystals; no quartz or mica are found in this rock.

Bunker Hill, the second highest peak in the range, (11,735 feet,) holds a central position, geologically as well as topographically; its neighborhood, after the Twin River region, has been the scene of the most varied upheavals and metamorphisms, and the strike of its rocks forms the greatest angle with the general direction of the range. Its mass consists of the various slate series

which form the main ridge to the north—here, in general, more highly metamorphosed—having a dip of about 45° to the eastward, and a strike of north 20° west, flanked on the east by the limestone body, which only extends to the northern edge of the cañon mouth.

Kingston Cañon is another of the characteristic gorges of the range, worn, in this case, through slaty rocks; its sides, except near the mouth, are less precipitous than those of Geneva Cañon, and yet sufficiently grand when one considers that looking up a lateral ravine, from the mining hamlet of Bunker Hill, one can see the southern summit of the peak of the same name, rising over 5,000 feet, in a horizontal distance of 10,000 feet. The general course of the cañon is at an oblique angle with the formation, which gives the appearance of a greater thickness to the rocks than they really have. A large dike of syenite, about 50 feet thick, of a close grain and dark-green color, occurs a mile or two from the mouth of the cañon, conformable with the inclosing rocks, and similar, in composition and position, to that in Santa Fé Cañon; it differs in that it is impregnated with iron pyrites, which do not appear in the former. Nearly parallel, and a few hundred feet above it, is a large quartz vein, about 15 or 20 feet thick, apparently conformable in strike with the stratification, but much contorted, especially in the ravines; parts of this have been found rich in silver, and the ore reduced in a small five-stamp mill in the cañon. These seem to mark a line of metamorphic action, for on the western slope of Bunker Hill, seemingly in a corresponding position, are found flexible slates, carrying cubes of iron pyrites and a grayish marbleized limestone, a metamorphic phase of one of the intercalated limestone strata of the slate series, or, possibly, an upper member of the quartzite series. While the cañon, in its lower part, is a narrow, precipitous gorge, between bare, rocky cliffs, along which the large quartz vein and several smaller ones can be traced for a considerable distance on the northern side, and the syenite dike, (or ironstone, as the miners call it, on account of its hardness,) on either side, it opens out above the axis of the eastern ridge, and at the bend, where the main tributaries come together, forms a pretty mountain valley, with smooth, grass-grown slopes. The northern fork of the cañon, with the two forks of Big Creek Cañon, form a longitudinal depression, separating the two high ridges, east and west, and probably occupy in part the axis of the main anti-

centrated in bands or bunches. It forms the southern foot-hills of Telegraph Peak, underlying the metamorphic rocks, which are dark-blue siliceous limestone-shales, dipping to the north and east at a low angle. At Telegraph Pass it is exposed on the eastern slope of the ridge, where it is traversed by a dike, about 15 feet wide, of white granulitic rock, containing sparse crystals of mica, and black crystalline grains, probably of tourmaline, concentrated in bunches throughout the mass; this dike has a northwest strike, which is the direction of the principal veins of this neighborhood. Granite forms the crest of the ridge, as far south as Mount Prometheus. This peak is chiefly conspicuous as forming the summit of Lander Hill, the spur in which have been found the richest veins of the district; its summit, and the flat-topped ridge at the head of Marshall's Cañon, are formed of rhyolite, which covers the eastern slopes of the ridge, and forms the head of the Park basin; while, on the main ridge south of Marshall's Cañon, are found the dark metamorphic slates of Telegraph Peak, dipping southeast at a low angle with a northeast strike, and separating the granite, on which they rest, from the rhyolite, which forms the saddle connecting this ridge with the hills north of Geneva. The rhyolite of Mount Prometheus is not a very characteristic variety, inasmuch as it contains but little free quartz, while that of the Marshall's Cañon ridge is very like a trachyte, or, in some respects, an older porphyry; but their mode of occurrence, geological relations, and certain mineralogical characteristics favor the assignment to them of a rhyolitic rather than a trachytic origin, while their resemblance to the older porphyries is confined to the compact matrix of a limited local occurrence.

The mass of Prometheus and its eastern slopes are composed of a brownish-purple vesicular rock, in which a microcrystalline feldspathic paste incloses crystals of glassy feldspar, magnesian mica in large quantities, and occasional grains of smoky quartz; largely disseminated throughout the mass, and lining the cavities, which are frequently as much as an inch in diameter, are spherulitic concretions of feldspar, whose occurrence is generally considered to be characteristic of rhyolitic rocks. On the western crest of Prometheus, toward the main granite body, this rock passes into a black pearlite, in which the spherulitic structure is still found, though not so prominently developed as in the former, nor with the same concentric structure. The vitreous paste

incloses crystals of white sanidin feldspar and black mica, but apparently no free quartz; it has a dark, glazed, weathered surface, and frequently a columnar structure, forming small pentagonal and hexagonal prisms. The line of contact of this rock with the granite, which has a north and south direction, is marked by a depression in the crest of the ridge west of Prometheus, and a ravine on either side, showing that the granite was decomposed, and hence more deeply eroded on this line; and the pearlitic texture would seem to be due to the reciprocal action of the granite on the rhyolite body. The main rhyolite of Prometheus is also very easily decomposed by atmospheric agents; hence, in the low saddle of the main ridge above Austin and in various depressions of the eastern spurs, it has been eroded off, and the underlying granite laid bare; here the granite is found to be so thoroughly decomposed on the surface that it crumbles into fine quartz sand at the touch, the feldspar having been kaolinized, and the mica only leaving its traces in stains of iron oxide through the mass. In several places on the eastern slopes, however, the granite is found in large rounded blocks, in a comparatively undecomposed state; these may not have been entirely covered by the flow of rhyolite, or their outer decomposed surfaces may have been entirely worn away by the action of erosion, and the undecomposed kernel left as now found.

South of the pass above Austin extends a flat-topped ridge, having a gentle slope to the eastward, which is formed of a reddish-brown porphyritic rhyolite; its compact, homogeneous, feldspathic matrix incloses small crystals of sanidin feldspar, with no free quartz as far as can be seen by a simple *loupe;* in the valley to the east this rock is found, having a lighter drab-colored matrix, inclosing, in addition to the feldspar, crystals of black mica.

Still further south, on the divide which connects this ridge with the hills north of Geneva, and in a line due south from Prometheus, occur similar rocks, and in the same relative position as on that peak; they are, however, more compact, and have not the spherulites which are found in those rocks. Still another variety of texture is found on the eastern limits of the body; as these, however, are, in a great measure, covered by the debris of the Park basin, they are not so clearly defined as the western limits. On the northern slopes of the hills, north of Geneva and near the Overland Stage road, is found a brick-red rhyolite, having an earthy homogeneous texture, probably the

result of solfataric action. At the foot of a northeastern spur of Prometheus, on the western edge of the basin, is found another partially decomposed variety, of white color, having small crystals of quartz disseminated through the feldspathic matrix.

The line of fissure of this rhyolite eruption, as has been seen, is about north and south; the southern portion of the body, or that which occurs in the slates, has a different character from the rock of Prometheus, which has broken through the granite, and is, by the occurrence of granite on the pass above Austin, isolated from the rest. There is no evidence to show that these rocks are cotemporaneous or the reverse, since they are not found in contact on the surface; whatever the origin of the more southern rocks, however, the summit of Prometheus evidently marks the vent through which the rocks, composing its slopes, have come to the surface.

The most productive veins in the district occur on the south slope of Lander Hill, the granite spur, which extends to the westward from Mount Prometheus; of those most extensively explored the majority have a northwest strike, and dip at a low angle into the hill to the northeast. In these veins has been found a system of fractures or faulting, in a north and south direction, occurring with such regularity and persistence as to suggest the idea that the surface of the spur has experienced a general downward movement to the westward, or, what seems more probable, that the interior core of the spur has been uplifted in the opposite direction, possibly at the time of the rhyolitic eruption of Mount Prometheus, the line of movement being generally parallel to this fissure.

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and a dip of about 30° to the northwest. Above the granite the gorge spreads out into an open longitudinal valley, in whose bottom are exposed the upturned edges of the metamorphic strata, which rest on the granite.

South of Geneva Cañon commences the main high ridge of the Toyabe Range, which rises suddenly in Geneva Peak to a height of 5,400 feet above the valley. The granite forms only the northern point of this ridge, extending along under its eastern edge, while the summit is formed of slates resting upon it. Geneva Peak consists of limestone shales, striking a little east of north and dipping south at a low angle. From here south as far as Bunker Hill, the main crest of the range is a high sharp ridge of various argillaceous and limestone shales, whose dip changes to the eastward a short distance south of Geneva Peak. The western slopes toward the interior valleys are generally quite abrupt, though owing to the fragile character of the rocks they are so covered with debris and soil that the details of structure are not very apparent.

On the eastern foot-hills the slates come in south of Geneva Cañon, having a northeast strike, and dip to the east and south, resting on the granite, and extending higher up into the range as one goes south; these are overtopped by a body of limestone, which first makes its appearance at Tar Creek, and is found in varying thickness along the eastern flanks of the range as far as Kingston. This limestone is a dark-blue, semi-crystalline mass, more or less metamorphosed throughout, and in many places assuming a foliated structure, so that it is difficult to determine the line of division between it and the slates. While the main ridge forms the eastern edge of the general anticlinal fold, there seems to have been a lateral fold between Globe Cañon and Santa Fé, and the strata are found to be much contorted and disturbed in this region. Near the mouth of Globe Cañon the limestone strata have a quite regular dip of 40° to the east, on the north side, striking north and south, those on the south side being irregular and much contorted, while still further south in Santa Fé they are tilted up at a generally steeper angle and have various strikes. On the eastern slope of Globe Peak, which attains the already very considerable height of 11,237 feet above sea level, are a succession of fissile slates of various green and purple shades, including a variety of quartzose mica-schist, containing, however, but a small proportion of mica, which un-

derlie and are conformable with the limestones that form the eastern extremity of the slope. Both slates and limestones are traversed by numerous veins of quartz, some of which show good bodies of galena; these veins have a north and south strike generally conformable with the stratification.

On the lower face of the foot-hills, just north of the mouth of Santa Fé Cañon, are the remarkable glacier polishings already mentioned. A thin seam of gray quartz, striking north 15° east, with a dip of 59° east, here forms the face of the spur; its somewhat undulating surface has, on the salient parts, over a tolerably continuous extent of several hundred feet, received a mirror-like polish, equal to the finest produced by artificial means, so that when the sun's rays strike upon it at the proper angle their reflection is visible as a bright point from a distance of many miles. The lines of striation, which are only visible on a close examination, are parallel to the line of greatest inclination. The surrounding rock, which is a somewhat metamorphosed and slaty limestone, has not been of sufficient hardness to retain any other traces of glaciers, though it is evident that to this agency must be attributed these polishings. Their position is indeed singular, at the foot of such a steep slope, and entirely on the outside of the cañon basin; the head of this cañon, which extends up to the northeastern crest of Bunker Hill, must have been filled by a glacier, whose lower end overlapped this spur, which closes up, in a measure, the mouth of the cañon, and the descending mass of ice and gravel has worn away the less resisting rocks, while this sheet of quartz received its present high polish. As far as known this is the only instance of such ice polishings in the range, though, as elsewhere remarked, the shape of the interior valleys seems to indicate that they were once filled by glaciers. In the limestones of Santa Fé Cañon were found the *fusilinae* already mentioned. Near the mouth of the cañon is a dike of dark green, fine-grained syenite, consisting of hornblende and white feldspar, the former occasionally in columnar crystals; no quartz or mica are found in this rock.

Bunker Hill, the second highest peak in the range, (11,735 feet,) holds a central position, geologically as well as topographically; its neighborhood, after the Twin River region, has been the scene of the most varied upheavals and metamorphisms, and the strike of its rocks forms the greatest angle with the general direction of the range. Its mass consists of the various slate series

which form the main ridge to the north—here, in general, more highly metamorphosed—having a dip of about 45° to the eastward, and a strike of north 20° west, flanked on the east by the limestone body, which only extends to the northern edge of the cañon mouth.

Kingston Cañon is another of the characteristic gorges of the range, worn, in this case, through slaty rocks; its sides, except near the mouth, are less precipitous than those of Geneva Cañon, and yet sufficiently grand when one considers that looking up a lateral ravine, from the mining hamlet of Bunker Hill, one can see the southern summit of the peak of the same name, rising over 5,000 feet, in a horizontal distance of 10,000 feet. The general course of the cañon is at an oblique angle with the formation, which gives the appearance of a greater thickness to the rocks than they really have. A large dike of syenite, about 50 feet thick, of a close grain and dark-green color, occurs a mile or two from the mouth of the cañon, conformable with the inclosing rocks, and similar, in composition and position, to that in Santa Fé Cañon; it differs in that it is impregnated with iron pyrites, which do not appear in the former. Nearly parallel, and a few hundred feet above it, is a large quartz vein, about 15 or 20 feet thick, apparently comformable in strike with the stratification, but much contorted, especially in the ravines; parts of this have been found rich in silver, and the ore reduced in a small five-stamp mill in the cañon. These seem to mark a line of metamorphic action, for on the western slope of Bunker Hill, seemingly in a corresponding position, are found flexible slates, carrying cubes of iron pyrites and a grayish marbleized limestone, a metamorphic phase of one of the intercalated limestone strata of the slate series, or, possibly, an upper member of the quartzite series. While the cañon, in its lower part, is a narrow, precipitous gorge, between bare, rocky cliffs, along which the large quartz vein and several smaller ones can be traced for a considerable distance on the northern side, and the syenite dike, (or ironstone, as the miners call it, on account of its hardness,) on either side, it opens out above the axis of the eastern ridge, and at the bend, where the main tributaries come together, forms a pretty mountain valley, with smooth, grass-grown slopes. The northern fork of the cañon, with the two forks of Big Creek Cañon, form a longitudinal depression, separating the two high ridges, east and west, and probably occupy in part the axis of the main anti-

clinal, the abrading forces having acted with more effect upon the upturned edges of the strata than upon their flanks. In the bottom, both above and below the bend, are large springs of cold water. Through this north fork and the south fork of Big Creek Cañon, which have an easy, natural grade, a road has been built, crossing the divide between them, at an altitude of 8,922 feet.

Opposite this divide is the highest point of the western ridge, Big Creek Peak, (10,265 feet,) whose upheaval is probably one phase of the lateral fold observed at Santa Fé, as it marks the angle of a change of direction in the strikes of the rocks forming the western ridge. Its summit and eastern slopes are in the slate, while on its western flanks is a body of limestone corresponding to that on the eastern side of the range. In the siliceous slates forming the very summit of this peak were found some traces of fossil remains, so much metamorphosed, however, as to be unrecognizable. To the north the slates appear to bend in direction somewhat to the westward, having a strike of about north, and a westward dip of 45°, of which a section is afforded by the Big Creek Cañon below the forks, while beyond Big Creek the direction of the strata changes gradually to the eastward, assuming the prevailing strike of the ridge north of this, about north 35° east, and still preserving a westward dip of 40° to 45°.

At the mouth of Big Creek Cañon is a small body of rhyolite, which forms the bed-rock of the cañon for a short distance, and extends along the lower foot-hills for a couple of miles to the southward; it is a very characteristic variety—a reddish-purple rock, of granitoid structure, containing crystals of quartz and mica. It seems to be an isolated eruption, and not accompanied by any extensive disturbance of the surrounding rocks, though, on the north side of the cañon mouth, it is bordered by a breccia, containing fragments of the adjoining slates and limestones. On the south side of the cañon the rock has an earthy and somewhat decomposed texture and brick-red color, probably resulting from solfataric action, of which the traces are still visible in the warm spring in the bed of the cañon just above the town. This brick-red variety was formerly used as refractory material in the construction of furnaces built here, during the early developments of the district, for smelting the galena

ores found in the slates of the south fork of the cañon. From here to the Point of Rocks extends a body of limestone, resting in general on the slates, with a westerly dip. In appearance it does not differ from the other limestones of the range, being somewhat granular in texture, of a dark-blue color, and largely intersected by narrow seams of white crystalline calcspar.

The extreme western angle of this western ridge, called, from its bare, craggy appearance, Point of Rocks, is composed of propylite, whose eruption has been accompanied by a very considerable modification of structure in the surrounding rocks; the limestones and slates are found to be dipping away from it on either side, and somewhat altered at the contact. The main central mass is a hornblendic propylite, having a greenish-white feldspathic matrix, inclosing crystals of opaque, white feldspar and dark green hornblende; along the summit of the ridge this rock has a distinctly columnar structure; at the head of the western fork of Kingston Cañon it is found in large lava-like blocks, having a dark, somewhat glazed surface; here it has a felsitic texture, the feldspar is semi-translucent, of a flesh color, and the hornblende appears in green spots, without any distinguishable crystalline structure. It is traversed here by a dike of compact, dark rock, resembling andesite, but carrying large, rounded grains of limpid quartz, apparently filling vesicular cavities through the mass. This central mass of hornblendic propylite is inclosed on the west and south by a body of quartz-propylite, which covers its flanks, forming the foot-hills on the edge of Reese River Valley, and to the south a portion of the crest of the ridge adjoining the limestone shales. This quartz-propylite is a later phase of the eruption, being separated from the main body on its southern edge by a tufa-like breccia, carrying flinty fragments; it contains more or less free quartz, and apparently no hornblende, while the central mass has hornblende and no quartz; that on the crest of the ridge has a yellowish paste, inclosing small crystals of white, opaque feldspar, probably oligoclase, which assumes a reddish color on the weathered surfaces of the western foot-hills, and is sometimes an entirely homogeneous, white mass, with free quartz.

A ravine marks the line of contact of the propylite with the limestone on the north, but on the ridge, where found adjoining the propylite, the limestone is grayish-white and granular, and dips to the northeast. On the south,

for a considerable distance along the ridge, are limestone-shales striking across it in an easterly direction, with a southerly dip, forming almost a synclinal with the limestones and shales in Smith's Cañon. A boulder of the Point of Rocks propylite was found in this cañon, which may indicate that that body extends under the ridge as far as this; as its origin was not discovered it can be merely a matter of conjecture.

From Smith's Cañon, south to Washington Cañon, extends a body of limestone, forming the flanks of the main ridge, now a single crest, having a strike parallel to its general direction, and resting on the slate series, which are found, higher up in the canon, conformably stratified, while the crest of the ridge is of white quartzite and granite, the former resting on the latter and dipping westward. These limestones and slates form a high, rounded hill, between Crane's and Washington Cañons, inclosing a considerable interior basin, at the head of the latter, which was not visited.

Beyond Washington Cañon the limestones have changed in direction, having an easterly strike and dipping to the northward, a change which, taken in connection with the extension of the granite body to the west at the head of San Juan Cañon, and the appearance of rhyolite at the mouth of this cañon, would seem to indicate a lateral fracture or fold at this point.

In these limestones between Washington and Cottonwood Cañons is the New Hope Vein, which when visited showed only the croppings of a large body of quartz, apparently striking north and south, carrying ores of silver, combined with the yellow oxides of lead and blue carbonate of copper. This was said to be very rich, yielding $800 to the ton.

The white quartzite body forms the head of Cottonwood Cañon, and the high point of the main crest above it. At the head of San Juan Cañon, however, the granite extends to the west side of the crest, succeeded, as elsewhere, by the quartzites, and lower by the slates, on whose flanks comes the rhyolite flow. This granite is noticeable on two accounts; first, that associated with large translucent crystals of orthoclase, it contains smaller crystals of a feldspar, which, from the brilliant play of green and blue colors on the cleavage facets, would seem to be a labradorite, though none of the crystals in the specimens taken were sufficiently well defined to afford a satisfactory crystallographical determination; secondly, that its quartz is mostly in distinct

crystals, hexagonal prisms about a sixteenth of an inch in diameter, with perfect hexagonal pointment; the rock has, moreover, a brownish-gray color, which seems due to the quartz, which is of a smoky brown. It contains very little mica or hornblende.

In the slates of San Juan Cañon above the forks are several veins of argentiferous galena. The remains of a rude furnace, constructed for the reduction of their ores, are still visible at the now deserted mining camp of San Juan. In the construction of this furnace, blocks of a yellowish, earthy, rhyolitic tufa, or breccia, which is found at this point on the south side of the cañon, were used.

The lower part of the spur south of San Juan Cañon is of rhyolite, which probably forms the low hills south of this on the western extremities of the spurs, which inclose the interior basins at the head of Cross's and the succeeding cañon. To return to the eastern slopes of the range, at the southern edge of the mouth of Kingston Cañon is a curious local occurrence of a rhyolitic breccia-like rock, forming the extreme point of the spur, and having, so far as known, no connection with any other body of eruptive rock; it is mainly an amorphous paste inclosing small, dark, flinty fragments, probably of altered slate, but in places a compact feldspathic matrix having a somewhat ribboned structure, and inclosing a large amount of free quartz in rounded grains.

The Bunker Hill slate series, with its dike of syenite, extends to the south of Kingston Cañon, forming a rounded mass of hills on the high eastern spurs of the main ridge, whose crest topographically bends round the head of this cañon.

In Brassfield Cañon, the second south from Kingston, is the first appearance of the great central granite body, which extends from here south nearly to Summit Cañon. The syenite dike here near the mouth of the cañon is almost identical in appearance and composition with that of Kingston, and likewise impregnated with iron pyrites. The granite is characterized by a very large proportion of quartz; it is a fine-grained white rock, containing a little white potash mica, and white, easily-decomposed feldspar. In contact with the slates which form the lower ends of the spurs, and rest upon it, it passes into a granulite carrying little or no mica, and in which the whole mass assumes a somewhat homogeneous texture. This granite body rapidly widens out as one

goes south, and a few cañons beyond forms the sharp aiguille-shaped spurs called the Needles, which are conspicuously seen from almost any point in the valley. Here the width of the granite body is from the very foot-hills to the crest of the ridge about five miles, and it continues with great thickness, so as to form the mass of the range east of the crest for six or eight miles further south. The main crest itself is generally formed of the upturned edges of the white quartzite strata, which rest on the granite, inclined to the west, and seem to increase in thickness to the south, attaining their greatest body in Summit Cañon. On the east of the main body of granite south of the Needles are brown quartzose rocks, forming at one point high jagged peaks, representing a considerable thickness. The nature and relations of these rocks have not been accurately determined. A later dynamical action is here rendered probable by the disturbed state of the granite body, which is thrown up in isolated broken masses, forming in one instance two flat lenticular-shaped bodies which rise a thousand feet from the slopes, their sides smooth and perpendicular, leaving an opening scarce a hundred feet wide between them.

At Indian Pass the granite body is found to be considerably thinner, as are also the quartzites; the granite forms steep craggy slopes at the mouth of the cañon, on which rest the quartzites, inclosing a huge quartz vein similar to that at Ophir Cañon, about 40 feet thick, striking conformably with the stratification, and with it dipping west; a smaller quartz vein, about six feet wide, with the same dip and strike, occurs higher up. The quartzites expose a comparatively small thickness, and as the slates form the upper part of the ridge, their debris may cover these to some extent.

On the western side of the divide, which is crossed by an old Indian trail, the interior basin at the head of Cross's Cañon is in the slates and limestones, which are still dipping west, but on the lower edge of the basin seem to dip slightly to the eastward, resting on the low rhyolite ridge which forms the lower foot-hills, and forming a commencement of the synclinal fold that is more distinctly seen further south.

The granite body has about the same thickness in Park Cañon, where a brown quartzose rock occurs to the east of it, forming the entrance to the cañon below the forks. The granite here has a brownish hue, and seems to contain little or no mica, but in its place a green mineral, probably hornblende.

It is fine-grained and has a general resemblance to that found in San Juan Cañon, and at the mouth of the South Twin River. A vein of mixed pyrites and galena, carrying some silver, has been prospected in the slates, above the granite, striking with the formation; a mill was commenced at the mouth of the cañon to reduce the ore from it. The main ridge of the head of the cañon is in the slates, and from here south to near Ophir Cañon continues in the slates and limestones, bending across the formation around the head of Summit Cañon.

Clay Cañon, the next south of Park Cañon, is cut through the granite body, which extends down to its very mouth.

In Summit Cañon the granite no longer comes to the surface. This is a steep, narrow gorge in the quartzite cliffs as high up as the Buckeye mine, where the formation changes; the cañon having a more gentle ascent, opens out into a high mountain valley in the slates and limestones, bending round the quartzite body to the north near its head. The lower part of the cañon affords an excellent section of the quartzite body, showing a thickness of over 3,000 feet of strata, mainly white, compact quartzite, with occasional intercalated strata of limestone which are metamorphosed into a white crystalline marble-like rock. In one of these, which seems to mark the dividing line between the quartzite and slate series, are the deposits of the Buckeye mine. These strata have a north and south strike, and dip at an angle of 45° to the west. In the lower part of the cañon they are traversed by a dike about 50 feet wide of a dark, compact rock, having a conchoidal fracture, in parts of which are found large rounded grains of limpid quartz, apparently filling previously formed cavities.

In Wisconsin Cañon, the next south from Summit, the quartzite series is represented only by a few of the white limestone strata, which are found at the mouth of the cañon; these are conformable in dip with those of Summit Cañon, but strike to the west of north. The rock from one of these strata is used for making lime. In the cañon above the forks, the slates are found dipping at a very steep angle, much confused, and highly metamorphosed. Near the forks is a dark-green hornblende schist; their structure is therefore not easily recognizable, though probably the same in general as that of the next cañon south.

Ophir Cañon presents a very interesting section through a synclinal fold in the slates inclosed between two bodies of granite. The lower end of the cañon is a narrow gorge cut through the granite body, on which rest metamorphic slates, having a north and south strike and dipping west. Near the contact of the slates and granite is the large vein which gives its name to the cañon, a dike-like body of quartz about 40 feet thick, dipping westward with the formation, at an angle of 50°. Above the Murphy ledge, which is near the axis of the synclinal, the slates dip about 45° to the east with the same north and south strike. At the upper forks of the cañon is found a green hornblende slate similar to that in Ophir Cañon. These slates rest on the granite, which at this point forms the crest of the ridge.

The faults found in the Murphy ledge on the north, and the fact that the Ophir vein, which is regular and unbroken on the south side of the canon, is represented on the northern spur by broken masses of quartz lower down, seem to indicate a general faulting and movement to the eastward of the rocks in this spur; such a movement, more extended, might perhaps account for the non-appearance of the quartzites in Wisconsin Cañon. The upper granite body of Ophir Cañon forms the saddle at its head and the main crest for a short distance to the north; and, to the south, extends across the head of Last Chance Cañon, its eastern limit seeming to have the same general direction with that of the propylite, by which it is replaced in the Twin River Cañons.

The first peak on the main ridge, south of Ophir Cañon—Mount Beseler—is of rhyolite, which rock covers the whole western slope of the range, from the granite crest to the Reese River Valley. The granite of this upper body is a compact, fine-grained variety, of dark color, due to the large proportion of dark, magnesian mica, in very perfect hexagonal crystals, entering into its composition; it contains, besides, quartz and white orthoclase feldspar; on the contact surfaces the mica seems somewhat decomposed and chloritic.

The rock of the lower body is a protogine-granite, coarse-grained though coherent, a white mass of quartz and feldspar, which are so intermingled as to render their crystallization very indistinct, inclosing foliated masses of dark-green chlorite or talc; this body extends along the eastern edge of the range, as far south as the North Twin River Cañon.

North of the mouth of the South Twin River Cañon is a small body of granite, resembling that of San Juan in its brownish hue, which seems here likewise to be due to the smoky condition of its quartz; like the latter it contains a very small proportion of mica, but the crystals of feldspar are so small that it is not possible to observe the labradorite-like iridescence of the feldspar of that rock. This granite passes on the west into a fine-grained rock, occurring in tabulated masses, having a reddish-brown weathered surface, which, to the naked eye, has the appearance of a greenstone, but, under the *loupe*, discloses a crystalline structure, in which small crystals of quartz and feldspar are distinguishable.

Still further south, as far as the Hot Springs, the eastern slopes of the range seem to be composed of metamorphic slates.

In the narrow gorges of the lower Twin River Cañons, the rugged grandeur of whose cliffs surpasses that of any of the other cañons of the range, the prevailing rock is a diorite, in general color from dark-green to black, consisting of a dark-green, hornblendic matrix, containing small crystals of white feldspar porphyritically imbedded, and locally a few crystals of limpid quartz, though the mass of the rock is without quartz; a light-green, transparent mineral frequently accompanies the feldspar, which may be an epidote. With unimportant variations in general appearance this rock extends from the propylite to the granite in either cañon, having an appearance of regular bedding, and interstratified, at different points, with highly metamorphosed siliceous clay-slates, which predominate near the line of contact with the propylite. The whole mass is much broken and confused, so that no satisfactory idea of the relative positions of these rocks was formed; hence, on the map they have not been distinguished by any distinctive color, but included in the slate belt, which occupies the same relative position further north; the whole mass is evidently metamorphic, as well as the eastern body of Ophir Cañon granite, and in no part of the range has the action of metamorphism been carried so far as in this region; a careful and detailed examination of which would doubtless afford many interesting developments with regard to the relations of granite to the more recent eruptive rocks, and of these to each other, as well as the action of either on the sedimentary rocks.

In ascending the cañons of the Twin Rivers a similar succession of rocks

is met: first, the small granite bodies; then the dark dioritic rocks, forming jagged, pinnacled cliffs on either side, and the high, sharp peak between the two cañons, and having a horizontal width of about two miles. A small extent of slates, in which some quartz veins have been prospected in the North Twin River Cañon, separates these rocks from the propylites, which stretch across these two cañons in a northwest and southeasterly direction. This would seem to be the direction of the propylite fissure from the fact that a somewhat similar succession of varieties of propylite, having the same general strike, is crossed in either cañon. The propylite forms only the entrance to the narrow gorges of the lower portions of these cañons, which open out above into large interior basins, with comparatively smooth debris-covered slopes; in the bottoms of these basins is found the propylite, extending up to near their heads, while, except along the line of contact with the slates on the northeastern limit of the body, the tops of the higher ridges are formed of rhyolite, which extends in a semicircle around these basins, forming the summits of the high points above the Hot Spring, and of the Mount Poston ridge.

The propylites are of colors varying from brown and green to mauve and white; they consist in general of a homogeneous, feldspathic paste, inclosing crystals of white, oligoclase feldspar and light-green hornblende, and, as accessory constituents, rounded grains of quartz and crystals of bronze-colored magnesian mica; only in the green varieties does the hornblende seem to form any considerable portion of the rock, and these are also generally free from quartz; the quartz is more abundant in the lighter-colored rocks, all of which, however, contain a certain amount of hornblende.

In the north fork of the North Twin River Canon the most quartzose variety of propylite found, of a whitish green color, was overlaid by a rhyolite of white, compact matrix, inclosing large grains of free quartz, which would seem to form a transition between the two rocks; the rhyolite next west of the Ophir Cañon granite has also some resemblance to a propylite, being a compact, reddish matrix, inclosing crystals of white feldspar with its quartz; but neither of these rhyolites contains hornblende or mica, one of which is always found in the propylites.

On the high ridge which separates South Twin River from the next cañon south,[1] a green breccia, of slightly foliated structure, inclosing purple-colored siliceous concretions, with quartz crystals disseminated through the mass, marks the line of separation of the mauve-colored propylite and the rhyolite, which forms the somewhat flat-topped peaks between the head of Twin River Cañon and the Hot Springs. This rhyolite has a reddish-gray, microcrystalline, feldspathic matrix, inclosing quartz grains, many of which are quite black, so that, at the first glance, they might be taken for mica, but no mica is found in the rock; the mass seems vesicular, but the larger cavities are shown to be the molds of feldspar crystals, and the same may be true of those which are so small that their form cannot be determined; how far this rock extends to the south is not known—probably for a considerable distance; it is, however, essentially the same rock as the Mount Poston rhyolite, and may be considered to form part of the same eruption. The main crest of the range, from Ophir Cañon south to Mount Poston, seems to form an independent line of fissure, having a direction nearly due north, this ridge being formed of rhyolites which have a remarkable uniformity in composition and general appearance; the rhyolite of Mount Beseler only differs from that of Mount Poston in that the latter has a more compact matrix and a conchoidal fracture, while the former is more vesicular and inclined to crumble on the weathered surfaces; it has a purplish-brown color, a rough, trachyte-like paste, carrying crystals of glassy feldspar and smoky quartz, with apparently no mica.

Mount Beseler is a conical-shaped peak, with debris-covered slopes, but the ridge is generally rather flat, being formed of rhyolite beds, having a general dip to the westward; just north of Mount Poston it spreads out into a wide, table-topped hill, on whose edge semicircular, crater-like depressions, surrounded by steep walls of columnar rhyolite, form the head of some of the streams which run together to form the Reese River.

Mount Poston rises a thousand feet above this ridge in a sharp peak, having on the west a slope of nearly 40°, covered by lava blocks, and on the east

[1] The topography of the map is here slightly at fault; the waters of this cañon take their rise at the northernmost of the peaks above the Hot Springs, and, flowing north, break through the eastern ridge in a gorge similar to those of the Twin River Cañons, indicated on the map by the short stream next south from the South Twin River.

almost perpendicular cliffs, in which a rude columnar structure is visible, and which extend for a considerable distance north and south, curving slightly to the eastward, and inclosing a semicircular basin at the head of the western fork of the South Twin River; this one looks from the summit down an almost sheer descent of three to four thousand feet.

The rhyolite flow covers the long western slopes of the ridge, and probably extends along them to the north as far as that of San. Juan.

The transverse ridge which connects the Toyabe with the next range west, across the head of Reese River Valley, was not visited; rhyolite probably forms part of this range, however.

BAROMETRICAL HEIGHTS.

6,608, Barometrical station in Marshall's Cañon.
6,339, Clifton.
7,512, Summit of road above Austin.
8,256, Mount Prometheus.
10,994, Geneva Peak.
6,400, Big Creek Cañon mouth.
8,922, Big Creek Pass.
10,265, Big Creek Peak.
9,610, Point of Rocks Peak.
5,635, Martin's, Smoky Valley.
6,782, Globe Cañon mouth.
10,547, Globe Cañon head.
11,237, Globe Peak.
6,247, Kingston.
11,602, Bunker Hill, south peak.
11,735, Bunker Hill, north peak.
8,075, San Juan.
10,982, San Juan Peak.
9,057, Indian Pass.

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NOTE.—These heights are based on the altitude of Camp Halleck, as determined by Lieutenant G. M. Wheeler.

6,738, Park Cañon mouth.
5,426, Alkali Flat, Smoky Valley, west side.
5,407, Alkali Flat, Smoky Valley, east side.
7,586, Buckeye Mine, Summit Cañon.
7,960, Twin River Company's office, Ophir Cañon.
10,285, Ophir Canon Pass.
6,653, Reese River, at Ione road
5,929, South Twin River Canon mouth.
12,143, Mount Poston.

## SECTION III.

### MINING AND MILLING AT REESE RIVER.

The Reese River mining district is about 160 miles due east from the western and nearly midway between the northern and southern boundaries of the State of Nevada. Strictly speaking, the term is locally applied to a small area, about two miles wide by seven long, within which the first discoveries of silver in that part of the State were made, and where is now situated the town of Austin. In a broader sense, it covers the whole of the mining country stretching along the Toyabe range of mountains, of which the exploration and partial development gradually followed the earlier discoveries just referred to.

The river, from which the name is derived, is a small stream that rises in the southern end and on the western slope of the Toyabe range, and flows thence, from south to north, toward the Humboldt River, along one of those meridional valleys that are characteristic of the great basin. From the head-waters of the stream to the Humboldt, the distance is about 150 miles. It is only in unusually wet seasons, however, that the river has sufficient body to reach the valley of the Humboldt. It gradually diminishes in size and, by evaporation and sinking into the soil, finally disappears altogether, leaving a dry bed to mark its course.

The first discoveries of silver were made in May, 1862, near the present site of the town of Austin, in one of the canons of the western slope of the mountains, about 80 miles south of the Humboldt River, where then the Overland Stage road crossed the range. Being on the great line of transcontinental travel it was comparatively easy of access, and the region was speedily occupied by prospectors and miners. Hundreds of outcropping veins were discovered and thousands of locations were made within an area of a few square miles; and although the larger number of these have failed to realize even the most moderate hopes of their owners, some of them have proved to be of great value. Since its first discovery the district has added several millions to the bullion product of the State, and a sufficient number of productive and profitable mines have been developed to afford a fair guarantee of a successful

future, especially under the more favorable conditions of easier access, cheaper labor, and improved methods of work.

Austin and vicinity.[1]—The city of Austin is the central point of the oldest mining district in this part of the State, and, at the same time, the commercial center and source of supplies of the outlying districts that have been gradually formed along the Toyabe range. It has several thousand inhabitants, and is one of the most important cities of the State. Until the completion of the Pacific railroad it lay in the great overland route; now it is connected by a line of stages with Argenta, on the railroad, 80 or 90 miles distant, by way of the Reese River Valley. The distance from Argenta to Sacramento in California is 396 miles.

The principal mining developments in the region of which Austin is about the center are comprised within a belt a half a mile or a mile wide and five or six miles long, extending in a northerly and southerly direction.

The main points within this belt are locally termed Union Hill, in the southern part of the ground, then, further north, Central Hill, Lander Hill, Telegraph Cañon, Emigrant Cañon, and Yankee Blade. The prevailing country-rock of this belt is granite, and all the veins that have so far proved to be valuable are inclosed in that rock. These veins are very small, and occur in series that have a generally parallel trend from northwest to southeast, though not without considerable variation, and dipping to the northeast at various angles between 15 or 20 to 60 or 70 degrees. They vary in width from a mere seam, that may be traced with difficulty, to two or three feet; the pay-streak seldom maintains for any considerable length a greater width than two or three inches, though frequently expanding, for short distances, to five or six, and, in a few exceptional cases, measuring eighteen or twenty inches. These veins have been disturbed in a remarkable manner by movements of the inclosing rock, by means of which they have been broken and displaced. Some of these faults are extensive, and are apparently caused by cross-fissures traversing the system of northwest and southeast veins in a northerly and southerly direction, and affecting them all to a greater or less extent; others are more local in their character and of less importance, as will be illustrated further on.

[1] The writer is indebted to the Hon. J. A. Boalt, Gen. E. A. Wild, Messrs. C. A. Stetefeldt, A. A. Curtis, C. F. Horn, C. C. Lane, and other gentlemen of Austin, for aid in obtaining information concerning the mining developments of the vicinity; also to Mr. J. M. Burns, formerly of the Reese River Reveille, for some statistical records.

The ores generally consist of rich silver-bearing minerals, comprising pyragyrite, proustite, stephanite, polybasite, tetrahedrite, argentiferous galena, zincblende which is believed to carry silver, copper pyrites, and iron pyrites. The proportions in which these components are mingled vary a good deal, certain portions of some veins carrying the richer silver minerals in such abundance as to make the average value of the ore several hundred dollars per ton throughout entire bodies of large extent, while in others the baser metals predominate to that degree that the average value of the ore is too small to pay for working. The gangue is chiefly quartz, manganese spar, which is very characteristic, and calcspar. Near the surface the ores are usually decomposed and altered, carrying hornsilver, and the chlorides, oxides, and some salts of the associated metals; they are locally known under the general term of "chloride," and, being easily worked, yielded, in early days, a large product with comparatively simple means of extraction. In depth the ores have suffered less change; they occur in compact form, and often present in their method of arrangement or deposit in the vein a beautifully regular and banded structure.

Lander Hill has always been the most important and productive part of the whole district. A very large proportion of all the bullion produced by the Austin mines has come from within a small area on the southern slope of that hill; and during the last two or three years, since the abatement of the prospecting fever, the mining work of the district, with one or two exceptions, has been chiefly confined to that locality.

The outcrops on the hillside are very numerous, and many locations have been made, some within ten or twenty feet of each other. Some of these outcrops have been proved by actual development to be well defined and persistent fissures; others are probably mere seams or branches that pinch out or unite with stronger veins in depth; and that many must disappear in this manner seems apparent from the fact that the number of veins or fissures cut in the deeper crosscuts and shafts, in various parts of the hill, bear a very small proportion to the number of outcrops at the surface in their immediate vicinity, which, if persistent, would appear below.

The developments on Lander Hill show that within this mineral belt,

running north and south, there prevails a zone, more favored than the rest, within the limits of which the northwest and southeast veins traversing it are especially rich in ores of high value, and beyond which the proportion of base metals is greatly increased. This zone, so far as understood, also has a north and south direction. On Lander Hill it may be from a quarter to a half mile in width. Its western limit is thought to pass through the Diana and the Savage mines, so that in passing from the southeastern to the northwestern portions of those claims a perceptible diminution of the richer and purer silver-bearing minerals, and an increasing predominance of baser metals, such as lead, zinc, copper, antimony, and iron, take place. Proceeding still further west the proportion of rich silver minerals to the baser compounds becomes still less, until the ore is quite too poor to pay for extraction.

It is within this "rich zone" that are situated the working and producing mines of the present day, for only those mines that produce rich ores can afford to work under existing conditions. As will be shown further on, the costs of mining in small veins, in which the ore is not uniformly distributed, are very great, because to obtain one ton of ore, many tons of worthless rock must be mined; in addition to which the costs of metallurgical treatment are also great. In the "rich zone," as well as in the poorer zone, are many mines capable of producing low-grade ores, whose development must wait until means of concentration of such ores are introduced, or cheaper methods of treatment are made practicable.

North Star Vein.—Probably the most important vein of Lander Hill, judging by developments thus far made, is that known as the North Star, on which are located the mines of the Buel North Star, the Manhattan, and the Timoke. The outcrop of this vein is on the south slope of the hill. It has a general direction of northwest and southeast, dipping, under the hill, or to the northeast, at an angle varying between 20 and 30 degrees; but both course and dip are very irregular, owing to the broken condition of the ground and the many faults and displacements of portions of the vein, that are the results of frequent movements of the inclosing rock. Like the other veins of Lander Hill, it is inclosed in granite. The walls are generally well defined, usually carrying a selvage, or gouge, of clay on either side of the vein. In some places the seam of clay is wanting, but the wall-rock, in the vicinity of the vein, is much de-

composed, forming a soft belt, one or two feet in thickness, that may be easily removed with a pick. In other places the vein is filled with a compact body of white quartz, either with or without ore, inclosed by hard, unaltered granite walls and accompanied by only a thin seam of clay. The width of the vein varies from two feet, and sometimes more, to a mere seam, expanding and contracting irregularly. In places it maintains an average width of 10 or 12 inches for a considerable distance, sometimes hundreds of feet, then narrowing so that the walls come almost together, leaving only a seam, that cannot be traced without difficulty. Not unfrequently the vein shows a width of four feet between its walls but consisting of two seams of quartz, between which is a mass of softened granite rock. This "horse," if such it may be termed, resembles generally the inclosing rock of the vein, but often has a banded or stratified appearance. It maintains itself, with varying width, for long distances, pinching out finally, the quartz-seams reuniting or, perhaps, being lost altogether by a contraction of the two walls, or by a division of the main fissure into numerous ill-defined seams and branches. The ore, as exposed in the drifts and stopes, usually appears in a pay-streak, an inch or two in width, now and then expanding to six inches, and in rare instances to twelve or eighteen. Thus, in the Buel mine, in one of the finest, if not altogether the best body of ore ever developed on Lander Hill, the pay-seam, consisting of ore worth $300 or $400 per ton, had a width of 18 or 20 inches, maintaining, for a length of over 100 feet, an average width of 12 or 15 inches. The ore consists of quartz, carrying more or less galena, copper pyrites, iron pyrites, and some zincblende, with a rich distribution of stephanite, pyrargyrite or ruby silver, polybasite, and fahlerz. Manganese spar is a characteristic associate of the gangue. Crystallized calcspar occurs with crystallized quartz in cavities. The veins of ore generally present a beautifully banded structure, the various minerals above named being arranged in parallel layers, indicating the order in which they were successively deposited on the side of the fissure.

The mode of occurrence of the ore in the vein appears to be in distinct bodies, which vary in size from mere pockets, or small bunches, to large deposits, 100 or 200 feet in length and depth. Large portions of the vein, even where possessing considerable width, are barren, or contain ore so

sparsely disseminated in small pockets that the whole mass is too poor to pay at anything like the present costs of extraction and reduction. On the other hand, courses of ore have occurred in all three of the mines above named, working on this vein, which, for a distance varying from 50 to more than 100 feet in horizontal extent, and as much, if not more, in depth, have been continuous and rich from one limit to the other. In the Timoke mine the pay ground, measuring about 80 feet in length, is said to have been rich from the surface down to the 350-foot level, where the vein was cut off by a "slide." The continuation of the vein, beyond the fault, was found also to contain pay ore, though, at the time of the writer's visit, of less value than it had been above.

Observations concerning the method of distribution of these ore-bodies, their position or dip in the vein, and other features, are too meager to show any great degree of uniformity existing among them as to their general characteristics. In mining them the chief object has been to get out the greatest quantity at the least expense, and comparatively little attention has been devoted to tracing out their limits, defining their form and position, and affording means of comparison of one body with others, or determining their relations to each other. A general coincidence of dip to the northwest, lying in the plane of the vein, is thought to exist among the larger bodies in this and other neighboring veins, though there are some exceptions. Many or most of the larger or richer bodies of ore occur in those portions of the vein that are intersected by the younger north and south veins, and are cut off abruptly by the "slides," or faults, resulting from such intersections, suggesting the possibility that the faulting may have had an influence upon the enriching of the vein at these points, a common observation in other mining regions where one mineral vein is enriched at its point of intersection with another; but the data are not sufficient to do more than suggest the probability. It is also noteworthy that the "rich zone" referred to on a preceding page has a north and south course, corresponding with these cross-fissures. The faults that have affected the North Star and other ore-bearing veins in its neighborhood most considerably are a series of veins or fissures of more recent origin having a general north and south course, and dipping more or less to the west-

ward; where most frequently observed by the writer, with an angle of 30 or 40 degrees from the horizon. Thus in the Timoke the vein is faulted by such a cross-course, having a north and south direction and dipping westerly 30 degrees, throwing the vein 30 or 40 feet. The Manhattan is similarly faulted, the original work of that company having been performed upon the outcrop, supposed to be the continuation of the Timoke, but reaching the fault at no very great depth; after which a vertical shaft was sunk at a point several hundred feet northeasterly from the outcrop, which struck the vein at a depth of 183 feet. The large body of the ore in the Buel is cut off by a cross-vein having similar course and dip to that just described. A fault of this character, as it appears in the Savage Mine, is illustrated on Plate XXVII, Fig. 3, concerning which some notes will be found further on.

The extent of the faulting by these north and south veins may vary from 30 or 40 feet to, perhaps, several hundred. Some of the most productive veins of the district that have thus been faulted have never since been recovered. The cross-veins are usually very narrow fissures, carrying little else than a seam of clay, and, so far as known to the writer, are not ore-bearing to any noteworthy extent.

Besides these more important faults, occasioned by the cross-veins just described, which, there is some reason to believe, traverse the entire system of northwest and southeast veins, affecting them all similarly or to some extent, there are numerous slighter faults or breaks, occasioned possibly by the same general movement of the ground, but in which the vein has broken into two parts, of which the upper has slidden, as it were, down hill, away from the deeper part. These movements, sometimes many feet in extent, are often very slight, frequently but a few inches. In the latter case the two parts of the broken vein are visible close together, the upper part, however, having slipped down so that the two walls no longer form continuous planes, as they did while in their original position. Such breaks are often repeated at short intervals and do not always create difficulty in following the inclination of the vein with a shaft. Sometimes, however, the fault or movement is great enough to throw the two portions of the broken vein so far apart that no indication of the deeper portion is visible in the shaft, or incline, that may have been sunk upon the upper portion from the surface to the point of disloca-

tion. In such case the portion of the vein continuing in depth is almost always to be sought by driving a cross-cut to the northeast, at right angles to the course of the vein, in accordance with the general rule that the surface rock or ground inclosing the upper part of the vein has slipped downward, leaving the deeper part in the standing ground above. This is illustrated in Fig. 1, Plate XXVII. *ABCD* represents the section of a vein that has been faulted, or broken, the ground inclosing the portion nearest the surface having slipped downward on the line, $a\ a'$, removing that part of the vein, *AB*, from its original position, indicated by dotted lines, to a point below, as shown in the drawing. A shaft, or incline, sunk from the surface on the part of the vein, *AB*, would encounter the country-rock at *B*, and a cross-cut driven thence in the country-rock, at right-angles to the course of the vein, would strike the continuation of the same at *E*.

The complication that may easily arise in such cases, giving frequent occasion for litigation, may be readily comprehended by supposing that the movement of the two disconnected parts of the vein *ABCD* has been so great that another similar vein occurs between the points *B* and *E*, as shown in Fig. 2. In this case, the surface of the ground inclosing the vein *ABCD* and the vein *F* has been moved downward, on the line $a\ a'$, so far that the continuation of the vein *F* is in the ground between *AB* and *CD*. A cross-cut, therefore, from *B* would first meet with the vein *F*. Should the latter present features similar to those of the vein *ABCD*, there might be difficulty in recognizing it as a different vein, thus giving occasion for a dispute between the owners or claimants of the vein *ABCD* and the owners of the vein *F*.

Timoke Mine.—This is the southeasternmost of the three mines that have been successfully worked on the North Star vein. Though having but a short extent of developed ground it has been one of the most profitable mines in the district, considering the amount of capital originally invested. It is opened by means of an incline, 80 feet from the northwest boundary line that separates the property from the claim of the Manhattan. The incline follows generally the dip of the ledge, which for a distance of 350 feet is about 30 degrees. The vein presents the general characteristic features already de-

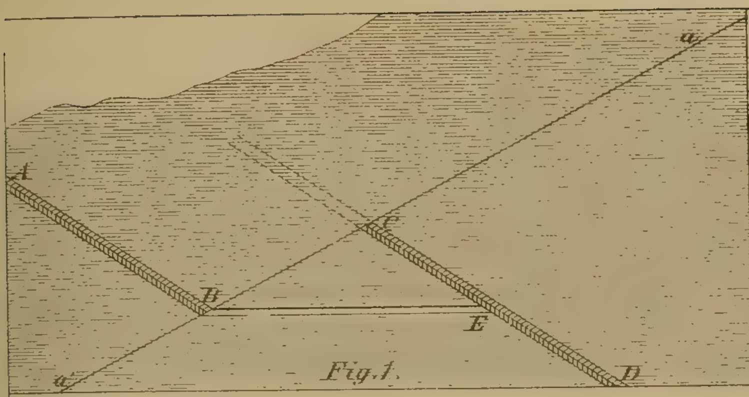



Fig. 1.

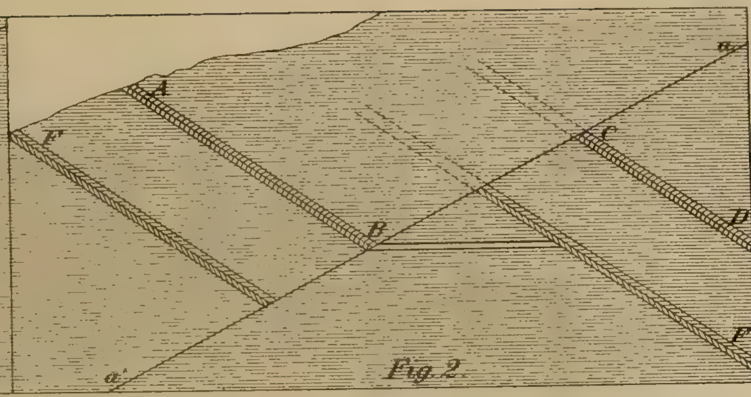



Fig. 2.

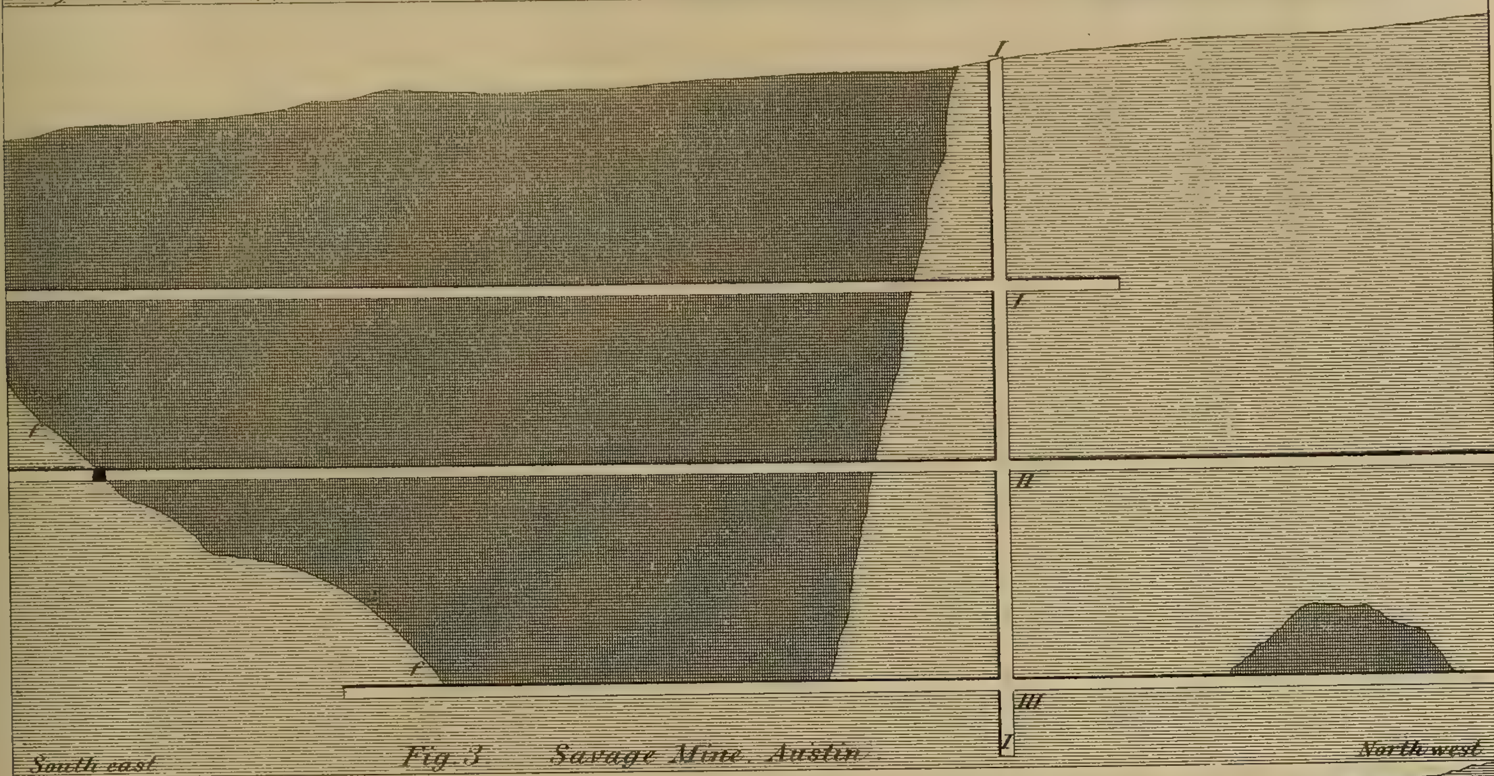



Fig. 3. Savage Mine, Austin.

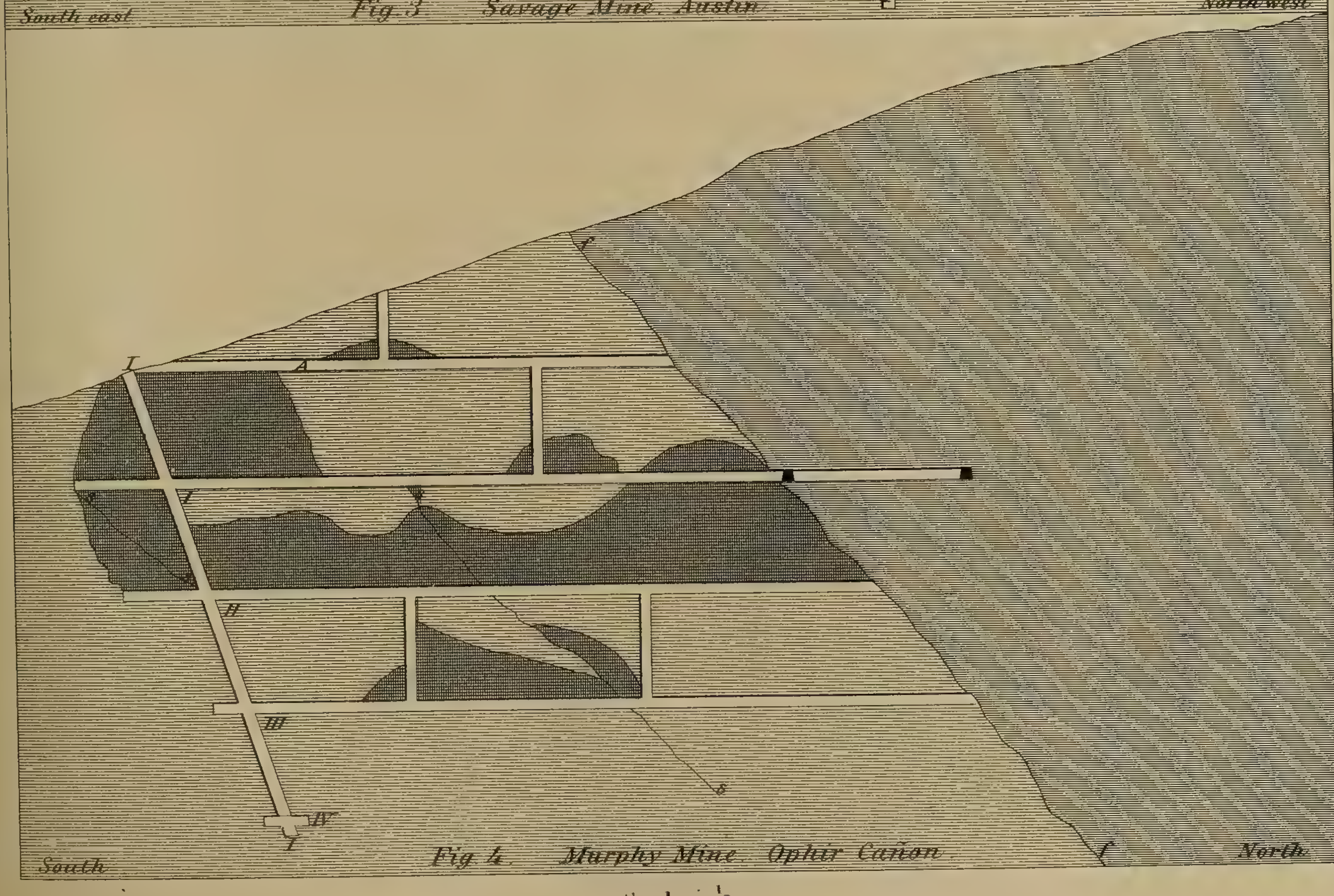



Fig 4. Murphy Mine, Ophir Cañon.

Scale: $\frac{1}{1260}$.

scribed in the foregoing pages. The ore-bearing quartz is from two feet to two inches in width, sometimes pinching out altogether, leaving only a small clay-seam between the walls of the fissure. The ore-seam, though generally narrow, is composed of rich silver-bearing minerals, associated with less base metal than is found further to the northwest. Thus far the productive portion of the ground has been altogether westward of the incline, that is, between the incline and the northwest boundary. Some exploring levels have been driven to the southeastward, but, so far as the writer is informed, they were quite unproductive, the vein being pinched up and barren.

West of the incline the ground has been almost entirely stoped out from the 350-foot level up to the surface; the average value of its milling ore is said to have been about $175 per ton. At 350 feet depth in the incline, the vein was cut off abruptly by a "slide" or cross-vein, having nearly a north and south course and dipping to the westward. As the continuation of the vein in depth was supposed to be in the ground above, the incline was driven on, but at an angle approaching more to the horizontal, dipping about 15 degrees, and at a distance of 40 or 50 feet from the slide the ledge was recovered, and followed thence for 30 or 40 feet further, when it was again cut off, and had not, when last visited by the writer, been found again, although the incline had been carried down 30 or 40 feet in its search. The vein between these two faults had been explored somewhat, and found to be ore-bearing, but not so productive as it had been above the slide first encountered.

The operations at the incline were conducted with but a small outlay for machinery or buildings. A small engine, eight-inch cylinder and sixteen-inch stroke, performed the whole of the hoisting, being set up at the mouth of the incline and driving by friction-gear a small winding reel. The water, of which there was considerable, was removed by a tight box-car, fitted with a valve in the bottom in such manner as to allow the car to fill when lowered into the sump and bring its load to the surface. According to the quarterly returns of the assessor of Lander County, the product of this mine from July 1, 1865, to September 30, 1868, had been about 975 tons of ore, averaging nearly $175 per ton in coin, or a product of about $170,000.

The statements of the superintendent show that the mine, though small, has returned profits to its owners very liberally in proportion to the amount

invested; it being represented that the assessments up to the time referred to had reached but $7,000, while the dividends returned amounted to $25,000.

In consequence of the impoverishment and loss of the vein, as before described, the product of the mine fell off in the summer of 1867. A vertical shaft, located northeast of the croppings and designed to strike the lode in depth, was commenced, but all work was subsequently suspended. The mine was idle in the summer of 1869.

Manhattan Mine.—The Manhattan is one of the most important and productive mines in the district. Its claim on the North Star vein is between the Timoke and the Buel. It commenced operations on that ledge in 1863, sinking an incline on the outcrop, which soon encountered a slide or fault, and the work was transferred to a vertical shaft, located several hundred feet to the northeast. This shaft, known as the "Manhattan," was sunk through the hanging wall of the ledge, striking it at a depth of 183 feet, and passing through it, was continued vertically, connections being made with the vein at lower levels by cross-cuts from the shaft.

The first level on the vein was made at the point where it was cut by the shaft, 183 feet below the surface; the second at 229 feet, the cross-cut to the vein being 87 feet long; the third level was made at a depth of 300 feet, the cross-cut to the lode being 327 feet long. Each of these levels was driven on the vein for a length of several hundred feet, developing some large and valuable bodies of ore. The most productive portion of the mine was found by the first and second levels, westerly from the shaft. In these levels the drift passed through not less than 100 feet of ore, which was stoped out from the second level to a considerable distance above the first, yielding a large amount of bullion with profit to the mine. The vein was less rich in the third level.

The development of the vein is carried on at greater depth by means of another vertical shaft, known as the "Oregon," located further up the hill, or to the northeast, and sunk vertically. This shaft was originally begun for the purpose of working the Oregon ledge, another of the same system of northwest and southeast veins, cropping out a little above the North Star. The Oregon ledge was opened years ago by an incline and produced ore of a high

grade; but the work, as originally commenced, was abandoned, and the shaft here referred to was sunk to cut the vein in depth. The shaft, however, passed through the supposed region of the vein without cutting anything that could be identified as the Oregon; and was then continued for the purpose of working the North Star vein at greater depth than could be conveniently reached by the Manhattan shaft. The Oregon shaft cuts the North Star vein, or what is recognized as such, at a depth of 511 feet from the surface; and at this point another level is opened on the vein, which is about 100 feet vertically lower than the lowest level opened by the Manhattan shaft. On this level drifts are run both east and west. The latter, in September, 1869, was 500 feet long. The east drift was not extended so far. They are connected by a winze with the level above and some productive stopes have been made in the intermediate ground; but the vein at this depth seems less abundant in rich ore than were some portions of the higher levels. The production of the mine has, however, been well sustained.

Throughout these works, the extent of which has been briefly indicated, the vein presents the general characteristics already described. The western portion of the mine appears to be the richest, but the difficulty of working it is much increased by the disturbances or movements which have taken place in the ground, breaking the continuity of the vein. The chief cause of this appears to be a cross-vein, striking about north and south, and dipping westward at an angle of about 30 or 40 degrees, along which line of fracture the country-rock seems to have moved. This slide or fault is encountered in each of the levels from the surface to the bottom of the mine. Search has been made on each level beyond the slide for the continuation of the vein, but without entirely satisfactory results. On the bottom-level the slide was found between 300 and 400 feet west of the shaft; by driving on through it a short distance, a vein, having the course, dip, and some of the general characteristics of the North Star, was found and followed for more than 100 feet; but it was poor in ore, almost entirely barren in places, and there was much doubt as to whether it was the continuation of the North Star or some other vein of the series.

This may illustrate one of the great difficulties experienced in working the mines of Lander Hill. The veins, or what are recognized as such near

the surface, are very numerous, somewhat irregular as to course and dip, so that their place in depth cannot be closely calculated, and many of them are of doubtful permanency.

Their width is also irregular, so that if one be cut in depth by a shaft or tunnel, at a place where the walls are pinched together, it might be passed without notice or identification. The faults, or slides, by which a whole series of veins may be displaced, are also many, and are imperfectly understood. The result is that when a vein is lost a search for its recovery may find one or more veins, but without making it possible to decide very clearly as to the identity of either of them. Under these conditions scarcely any of the companies, mining at any considerable depth, have any positive assurance that they are working on the same vein upon which their claims were located on the surface.

The field open for litigation under this state of affairs is very wide. In effect, however, the number of companies working at present is very small, the high costs of all mining operations having caused the suspension of work on most claims; and the policy generally adopted by those who continue is to take whatever they can get wherever they find it, until an adverse claim is proved to be good; and this, under existing conditions, is not often practicable.

The work of the Manhattan mine is a fair illustration of the general method of operations in the other mines of the district, and its accounts probably furnish the most reliable data concerning the costs of mining and milling. Some statements of this nature are given below, for which the writer is indebted to Mr. A. A. Curtis, the agent of the company at Austin.

The vertical shafts, through which the work of the mine is carried on, are about 12 or 13 feet by 4 feet, inside the timbers, divided into three compartments, two for hoisting and one for pumping. The ground is firm, and the timbering consequently light, the shafts being lined with plank, without heavy timber framing. Hoisting is done with cages similar to those in use in Virginia City, already described. The water is raised from the bottom of the Manhattan shaft by a six-inch force-pump. The power for hoisting and pumping is furnished, at that shaft, by a steam-engine, having a cylinder of 12 inches diameter by 24 inches stroke. Friction-gear is used for hoisting, and on the same shaft which carries the drivers for the winding drums is a

toothed pinion, geared to the driving wheel of the pump. The Oregon shaft, having about the same dimensions as the Manhattan, and resembling it in general features, was 553 feet deep in September, 1869. The average cost, per foot, of sinking this shaft, including expense of timbering and of operating the hoisting and pumping machinery, amounted to $68 93.

An idea of the items making up this total is presented in the following statement of costs for the month of March, 1868, during which 42 feet were sunk, the shaft being, at that time, between 300 and 400 feet deep:

| | Per foot. |
|---|---|
| Sinking, 42 feet | $26 38 |
| Hoisting machinery, engineers, carmen, &c | 13 29 |
| Materials consumed, timber, lumber, &c | 15 89 |
| Fuel | 6 77 |
| Supplies: powder, candles, fuse, steel, &c | 2 42 |
| Work in preparing and placing timbers | 1 67 |
| Hauling fuel, lumber, &c | 2 36 |
| | 68 78 |

This shaft is substantially equipped with hoisting and pumping machinery. One engine, having a cylinder of 10 inches diameter and 20 inches stroke, is already in place for hoisting. The pumping engine and pump, for which provision is made, are not yet in place; the water is now raised by a water barrel.

The total cost of sinking this shaft, incurred previous to December 31, 1868, appears from the accounts of the company to amount to about $58,000, including all outlay for buildings, machinery, &c., &c.

The costs of mining, per ton of ore produced, are very large, as they naturally must be where the vein is so narrow that the quantity of workable ore produced is but a small proportion of the whole amount of rock broken and raised to the surface.[1] These costs vary considerably from month to

[1] In J. Ross Browne's report, Mineral Resources, 1868, concerning the Florida mine, on Lander Hill, it is said that 4,000 tons of country-rock were mined in producing 317 tons of ore, or one ton of ore in $12\frac{6}{10}$ tons of rock brought to the surface.

month, on account of the changeable character of the ground; since the proportion of necessary dead-work to the quantity of ore obtained will vary according to the richness of the vein at any given time; and much of the expense of mining must be incurred whether the product be great or small.

The accounts of the mine show that the average cost of drifting 500 feet from the bottom of the Oregon shaft was $10 76 per foot. The average cost of stoping or breasting ore, already rendered accessible by drifts or tunnels, is equal to $25 or $30 per ton.

To the foregoing are to be added the costs of handling and moving ores, hoisting and pumping, maintaining and operating the machinery, &c. The costs of timbering are light, because the veins are small and the ground is comparatively firm.

During fifteen months previous to January 1, 1868, the costs of mining 2,336$\frac{1828}{2000}$ tons of ore amounted to $105,342 12, or an average of about $45 per ton. In 1868 these costs were still larger, as may be seen by the following statement, showing the expenditures for mining work during that year, when 1,988 tons of ore were produced. The whole number of days' work employed in the mine, for extracting and for prospecting, was 20,613, of which amount 13,662 days were expended in the first-named department of labor, and 6,951 days in the latter.

| | |
|---|---|
| The cost for labor in extraction was | $54, 910 00 |
| And dividing other items of expense in the same proportion, we have for cost of running cars and machinery and repairing tools | 18, 636 02 |
| Supplies, fuel, timber, and sundries | 22, 853 43 |
| Cost of sorting ores, and other incidental labor | 3, 875 00 |
| | 100, 274 45 |

The additional costs for prospecting work were—

| | |
|---|---|
| For labor, 6,951 days | $27, 836 00 |
| Cars and machinery | 9, 481 73 |
| Supplies, fuel, timber, &c | 11, 627 44 |
| | 48, 945 17 |

We have, in this case, an expense, per ton, for mining, of $50 44; and for prospecting, an expense, per ton of ore produced from the mine, equal to $24 61; making a total of $75.

If, to the actual mining costs given above, amounting to $45 per ton in 1867, and to $50 44 per ton in 1868, the costs of milling, averaging $35 per ton, be added, it will be readily seen that the ore must yield, at least, $80 or $85 per ton in order to meet the expense of extraction and reduction alone, without allowing anything for extraordinary outlay in prospecting, amounting, as we have seen, in 1868, to $24 61 per ton, or for the other expenses of the business, such as general improvements, repairs, and incidentals; since the figures above given include nothing but expenses actually incurred in extracting the ore from the mine and treating it in the mill.

The nature and amount of other expenses may be shown by the following "Statement of Earnings," taken from the company's published report for the year ending December 31, 1868:

| | | | |
|---|---|---|---|
| Ores from North Star, or Manhattan mine, 1,954 $\frac{1974}{2000}$ tons, producing | | $290,227 79 | |
| Mining expenses | $148,269 89 | | |
| Milling expenses | 77,932 73 | | |
| | | 226,202 62 | |
| Net profit on company's ores | | | $64,025 17 |
| Profit on working custom ores in mill: | | | |
| 3,443 $\frac{1385}{2000}$ tons, producing | 912,954 47 | | |
| Milling expenses | 135,342 05 | | |
| | | 777,612 42 | |
| Cost of same, returned to customer | 864,310 87 | | |
| Less custom price for milling | 156,109 87 | | |
| | | 708,201 00 | |
| Net profit on custom ores | | | 69,411 42 |
| Royalty on ores worked by other parties | | | 9,311 88 |
| Rents | | | 157 00 |
| Premiums on bullion | | | 23,188 74 |
| Premiums on drafts on New York | | | 7,075 13 |
| | | | 173,169 34 |

Less other expenses:

| | | |
|---|---|---|
| Freight on bullion, Austin to San Francisco | $18,825 73 | |
| Freight and insurance, San Francisco to New York | 20,245 89 | |
| Discount on drafts on San Francisco | 6,015 83 | |
| Reclamations on bullion | 1,956 62 | |
| Mill repairs | 5,355 17 | |
| Work on Oregon mine | 1,820 00 | |
| Taxes | 9,923 60 | |
| Fire insurance | 2,644 89 | |
| Interest account | 965 82 | |
| Austin expense account | 4,156 75 | |
| New York expense account | 8,177 57 | |
| Sundry losses | 801 43 | |
| | | $80,889 30 |
| Net earnings from mine, mill, and all other sources, during 1868 | | 92,280 04 |

The following statement of disposition of earnings shows the various outlays for general improvements not included in the foregoing:

| | | |
|---|---|---|
| Surplus on hand, December 31, 1867 | | $64,892 70 |
| Earnings in 1868 | | 92,280 04 |
| | | 157,172 74 |
| Expended in Oregon shaft | $39,435 90 | |
| Oregon hoisting works | 12,494 04 | |
| Manhattan hoisting works | 1,553 69 | |
| Mill improvements | 10,721 22 | |
| General improvements | 2,526 10 | |
| Ethan Allen mine | 4,989 52 | |
| Real estate purchased | 2,290 05 | |
| Office furniture | 89 22 | |
| | | 74,099 74 |
| Leaving on hand supplies and funds amounting to | | 83,073 00 |
| To which may be added the value of 94 tons of ore | | 12,000 00 |
| Making in all | | 95,073 00 |

From the foregoing accounts may be deduced the following results:

| | |
|---|---|
| Average yield, per ton, of Manhattan ores | $148 45 |
| Average mining expense, per ton, of Manhattan ores | 75 84 |
| Average milling expense, per ton, of Manhattan ores | 39 86 |
| Average yield, per ton, of custom ores | 265 10 |
| Average milling expense, per ton, of custom ores | 39 30 |
| Average milling price, per ton, of custom ores | 45 30 |
| Average profit on Manhattan ores over actual costs of mining and milling | 32 75 |
| Average profit on custom ores | 20 15 |
| Average of other expenses, amounting to $80,889 30, on all ores, from Manhattan mine and from customers, 5,398 tons, per ton | 15 00 |

The Manhattan Company, like many mining enterprises, has had a varied experience of good and ill-fortune. In the earlier years of development the outlay for mining and reduction works far exceeded the value of their product, and in May, 1866, the owners found themselves with a mine opened for work and equipped with hoisting machinery, a mill with only a part of its present capacity, and a debt of $180,000, in the shape of bonds issued to cover their obligations. During the eighteen months ensuing, the mine was unusually productive, the net earnings from September 30, 1866, to January 1, 1868, amounting, according to the books of the company, to $245,355 64, discharging the debt and adding considerably to the equipment and improvements of the mining and milling works; $34,000 having been expended, within that period, in improvements and repairs at the mill, and $10,000 on the hoisting works of the North Star and Oregon shafts.

According to the quarterly returns of the assessor for Lander County the product of this mine from June 30, 1865, to June 30, 1869, amounted to more than $800,000.

Buel.—The Buel North Star is the northwestern neighbor of the Manhattan, on the North Star ledge, having a claim of 1,000 feet in length. It has been working several years with variable fortunes, but of late has placed itself among the largest producing and, probably, most profitable mines of the district. The general features of the vein need no further description. The work on the mine was begun on the outcrop by an incline which followed the dip of the ledge pretty nearly, losing the vein repeatedly by reason of its

frequent breaks and slides, but recovering it again without much trouble, until at a depth of 384 feet from the surface, measured on the dip of the ledge, a fault was encountered by which the vein was cut off. The incline was continued 66 feet further without finding traces of the ledge, and then a level was driven horizontally from the bottom of the incline, in a northeasterly direction, in the belief that the vein was in the ground above. At a distance of 225 feet from the bottom of the incline, or 675 feet from its mouth at the surface, the lost vein, or what is believed to be such, was found again, carrying, at the point where cut, a good seam of ore, which subsequent developments proved to be one of the most valuable discoveries ever made on Lander Hill. From the point in the vein intersected by the cross-cut, drifts were run east and west. The former, at about 30 feet from the starting point, encountered another slide, striking north and south and dipping west, which cut the vein entirely off; but the western drift developed a body of ore more than 100 feet in length and extending an equal or greater distance above the level, having an average thickness of 12 or 15 inches of solid mineral. The general characteristics of this occurrence were such as have been already described, but the ore was unusually rich in silver, and proved to be a source of wealth to the company.

In order to carry on the work of mining on deeper levels the Buel North Star Company formed a consolidation of interest with the Lane and Fuller Company. The latter, chiefly owned by the principal stockholders of the former, had sunk a vertical shaft, located higher up the hill, about 800 or 900 feet northeast of the incline, and already about 300 feet deep at the time of the consolidation of the two concerns. The sinking of this shaft was continued by the new company, under the name of The Lane and Fuller, and, at a depth of 400 feet, was connected with the vein by a drift, which, running with an irregular course, but generally in a southwesterly direction, cut the ledge at a distance of 200 or 300 feet from the shaft. From this point the drift is carried on some 300 feet in the ledge, and when visited by the writer in September, 1869, had opened an excellent body of ore. In the western extremity the ore was less rich, as it was there approaching the region of the base metals; but there was a stope over 100 feet in length in which the show of ore was as fine as any ever seen in the mine. The eastern limit of this ore-

body is a fault, or slide, which appeared to be the same that had been encountered in the upper levels, and which has already been noticed. The distance, upward, from this lower level to the deepest level opened by the incline is 230 feet, measured on the dip of the ledge, and a large portion of this ground appears to be productive.

At the time referred to there were 45 men at work in the mine. The production of ore was varying between 100 and 200 tons per month. All hoisting and pumping was done through the Lane and Fuller shaft, the old works at the incline having been abandoned. The shaft was still sinking and had reached a depth of 500 feet. It is sunk in three compartments, two for hoisting and one for pumping. It is cased with plank, no heavy frames of timber being required. The shaft is provided with two engines, each having cylinders 10 inches in diameter and 20 inches stroke; one of these is used for hoisting, driving friction-gear; the other is employed in pumping; but both are so placed that one may do the work of the other if necessary. The pump is a force-pump, six inches in diameter and four-foot stroke. The object of this shaft is not only to work the North Star ledge, but to afford the means for the discovery and development of other veins. It has already cut a number of ledges, some of which are thought to be identified with some of those cropping out on the hill below the shaft; others of which are claimed as new.

The veins cut in the shaft to the depth of 300 feet are described as follows:

| | Depth. |
|---|---|
| Black ledge, cropping at the surface, near the shaft, cut at | 10 feet. |
| Florida, cropping at the surface, extension of Florida company's vein | 103 feet. |
| Oleander, cropping at the surface, extension of Oleander company's vein | 130 feet. |
| Miner, claimed as hitherto unknown | 140 feet. |
| Tyler, claimed as hitherto unknown | 160 feet. |
| Dyer, claimed as hitherto unknown | 233 feet. |
| Warren, claimed as hitherto unknown | 285 feet. |

The last named is described as four feet thick and carrying valuable ore. It has been worked to some extent. At a depth of 400 feet, a drift is carried in a northeasterly direction from the shaft, which at a distance of little

more than 100 feet cuts a ledge supposed to be the Warren. The exploration of this was in progress in September, 1869, but no very definite results had then been obtained.

The costs of mining and milling operations appear to be no less in the Lane and Fuller than in the Manhattan mine. The company published a report for the year ending June 30, 1869, from which the statement of expenditures given below is drawn. The account is not sufficiently analytical in its character to show the relation existing between the cost of prospecting and improvements on one hand, and the actual mining and milling expense on the other. During the year, however, the shaft was sunk from a depth of about 300 feet to a depth of 445 feet; 3,282 feet of drifts were run. An additional engine of 30 horse-power was placed at the shaft-house and the pump was provided and set in the mine. A fire-engine and steam saw were also purchased. The product during the time was $1,029\frac{558}{2000}$ tons of ore, which yielded $224,050 38, averaging $217 68 per ton. It will be seen that the total expenditure for current operations, prospecting and improvements taken altogether, amount to over $200 per ton of ore produced.

*Expenditures of the Lane and Fuller mine for the year ending July* 1, 1869.

| For— | Amount. | For— | Amount. |
|---|---|---|---|
| Hardware | $3,253 07 | Interest and exchange | $2,246 86 |
| Incidental expenses | 8,107 18 | Expense | 5,750 00 |
| Lumber | 10,203 79 | Wood | 8,458 91 |
| Labor | 97,611 25 | Contract | 5,140 31 |
| Machinery | 3,017 63 | Mine | 400 00 |
| Supplies | 9,930 03 | Milling | 46,178 24 |
| Blacksmithing | 40 11 | Litigation | 2,109 85 |
| Charcoal | 934 02 | Tax | 3,896 64 |
| Telegraphing | 494 76 | Assay | 253 50 |
| Hauling | 1,478 45 | Freight | 911 48 |
| Construction | 2,417 00 | | |
| | | | 212,833 08 |

The total product of this mine from September 30, 1866, to July 1,

1869, appears, from the assessor's returns and other sources of information, to be about $325,000, coin.

There are many other mines on Lander Hill, some of which have been extensively developed; but the high price of labor, the great cost of working such small veins, and the expensive methods of treatment that are necessary in order to extract the silver from the ore when once obtained, have caused, at least for a time, a suspension of operations in most of them. A few men were still working on persistently in 1868, when the White Pine discoveries began to attract attention, and such was the excitement that followed this event, that both labor and capital were diverted from all the neighboring localities toward the new El Dorado. Owing to this and other causes many of those who were then working at Austin suspended labor; and in 1869 only two or three companies were still active. The chief of these were the two mines already described.

Some of the other principal mines of Lander Hill that have been worked considerably, and until within a year or two, are the Troy, Florida, South American, Magnolia, and Diana. The Savage and Great Eastern, also on Lander Hill, were very productive mines in former years, but having exhausted their known sources of ore, have been idle for a longer period than those just mentioned.

The Whitlatch Union, on the southern slope of Union Hill, a mile or more south from Lander Hill, has been an important and productive mine, but is now in the same condition as the last-named; and its neighbors, the Camargo and others, have long been idle.

In Yankee Blade Cañon, two or three miles north of Lander Hill, is situated the Yankee Blade mine, opened and extensively worked some years ago, producing some bullion, but allowed to lie idle for several years. This mine has again resumed operations under a new organization. In this portion of the district are many other ledges, partly developed, but for the present closed, partly owing to want of capital and partly to serious disappointments that have destroyed confidence in their value. A detailed description of all these mines, which in their natural features and methods of development have a great deal in common, and some of which have been already described in other works, is unnecessary here. A few notes concerning the more im-

portant of them will suffice to indicate the extent to which they have been developed.

Troy.—The Troy ledge crops out on Lander Hill, just below the Florida, and is worked by an incline, which is located close by the Lane and Fuller shaft, just referred to. The company claim 800 feet on the ledge. Its course is north 40° west, true, and its dip 20° to 30° northeasterly. The incline, dipping with the vein, is 284 feet deep, from which drifts, from 200 to 400 feet in length, have been run in the vein on three several levels, at 158, 222, and 284 feet from the surface. The chief source of ore was found in the upper portion of the ground. The ore occurred in pockets and bunches, of a high grade in value, but not in large bodies. It resembles generally that already described. The incline is provided with very well arranged hoisting machinery, an engine, with a 12-inch cylinder, driving friction-gear. The cost of these hoisting works, including boiler, engine, winding apparatus, &c., was about $7,000. The average value of the ore produced is about $190 to $200 per ton. On the 28th April, 1868, the books of the mine showed an expenditure of little over $70,000, while the production amounted to little over $35,000 in coin.

According to the quarterly returns of the assessor for the county the total production of this mine, from June 30, 1865, to June 30, 1869, amounted to 278 tons of ore, averaging little over $190 per ton, or, in the aggregate, about $53,000 in coin.

Florida.—The Florida ledge is worked by the New York and Austin Silver Mining Company. Their claim, originally 800 feet in length, is reduced to 550 by compromise with the Magnolia, a company adjoining them on the west, working on what was formerly located as a separate vein, but afterward proved to be the same as the Florida, or one of its branches. The course of the ledge is north 50° west, dipping northeasterly at about 30°. The incline by which it is worked is 500 feet long, from which drifts are run on five levels, generally 100 feet apart. These levels, excepting the lowest, are from 100 to 200 feet in length, and have developed a large body of rich ore, which was from 100 to 130 feet in length, measured along the drift, the vein being from four or five to sixteen inches wide in places. From the 400-foot level up to the surface everything known to be worth mining, within the limits

explored, had been stoped out in 1868, shortly before the mine closed; but there was still a good show of ore between the 400-foot and 500-foot levels, where the ground was standing. According to the quarterly returns of the county assessor the product of this mine, from September 30, 1866, to June 30, 1869, amounted to about 1,000 tons, yielding about $236,000 in coin.

The profits of this work are said by the superintendent, Mr. E. A. Sherman, to be about $100,000, currency, which amount, however, has been re-invested in machinery for the mine, and in the prosecution of other exploring works. These latter consist mainly in two vertical shafts, located on the ridge of the hill, or "divide," overlooking the opposite valley. These shafts were projected to be sunk to the depth of a thousand feet or more, with the view of striking and working some of the ledges belonging to the company and cropping out on Lander Hill; also, with the somewhat visionary expectation of finding the many seams and fissures of the surface concentrated in one grand vein below. The Sherman shaft had reached a depth of 250 feet. It is 15 feet by 5, divided into three compartments, cased with three-inch plank. It is liberally provided with hoisting power, an engine, with cylinder of 16 inches diameter by 34 inches stroke, driving friction gear for hoisting, and furnished with pumping gear. Two tubular boilers, 50 inches in diameter, supply steam. The sinking of the shaft to depth mentioned above, and equipment of machinery, cost $56,000. The Burns shaft is located 1,500 feet west, and is similar in character and purpose. It is not yet provided with machinery. It is 90 feet deep, and has cost $12,000. The work on both these enterprises had been suspended in the summer of 1868. Neither had, at that time, made any important developments. The mine itself suspended operations in 1869.

DIANA.—The Diana is situated below most of the important veins on Lander Hill, and is on the western portion of the ground, its ores partaking of the character of the baser zone, that lies west of the richer mines. Its course is north 15° west, true, and it dips from 45° to 50° easterly. The claim is 1,200 feet long. On the surface the vein was stripped for 180 or 200 feet in length, yielding rich chloride ores; in depth it has been worked some 300 feet, yielding some ore of high grade, but the greater part of it is mixed with base metals, which not only diminish the value but increase the cost of treatment.

The distribution of ore has thus far proved to be irregular, even as compared with other mines of Lander Hill, increasing consequently the costs of mining. During the summer of 1868 the work on this mine was suspended, two years or more of careful management, under the superintendence of General E. A. Wild, having shown that, under existing conditions and prices for mining and milling, it cannot be profitably worked.

According to the returns of the assessor the mine has produced, from June 30, 1865, to January 1, 1869, about 900 tons of ore, averaging about $130 per ton, or aggregating $117,000 in gold.

Savage.—The Savage has been one of the most important and productive mines of Lander Hill. The ledge crops out not far below the North Star, and the developments of the mine are nearly south from the work of the Buel mine on that ledge. The course of the vein in the Savage is north 54° west, true, dipping quite regularly, at least to a considerable depth, at about 56°. The vein is one of the best defined and strongest in the district, maintaining a width of 12 inches, and sometimes much more, throughout a large portion of the work. The surface yielded a good deal of rich "chloride" ore. In depth the mine is opened by an incline, *I*, extending 350 feet, from which three levels have been driven, as shown in the section represented in Fig. 3, Plate XXVII. The mine was filled with water, below the first level, at 140 feet depth, when visited by the writer, and the section is therefore prepared from memoranda furnished by the superintendent, Mr. Hurlbut. The figures may vary slightly from the actual truth, being given from memory, but they will serve to illustrate some interesting points in the mode of occurrence of the ore-courses in this and neighboring veins.

The incline is 450 feet from the southeast boundary line, dividing the property from the Southern Light. The pay-ore has been almost entirely between the incline and this boundary. The first level was driven to the line, and, excepting a few feet near the shaft, was in good ore throughout the whole distance. The second level found the pay-ground a little further from the shaft than in the level above, and, being driven through it, encountered a slide, or fault, *f f*, at about 50 feet before reaching the boundary line. The cross-vein, causing the fault, has a nearly north and south course, and dips westerly 35° to 45°. The third level found the pay-ground still further from

the incline, and the line of faulting at 250 feet from the incline, or 200 feet from the boundary. The section shows accordingly that the fault approaches the shaft in depth, diminishing, with every foot sunk, the extent of the ore-body. On the opposite side of the shaft, or incline, the ground has been drifted through, but little of importance has thus far been found.

Some efforts have been made to find the continuation of the vein beyond the fault, and for this purpose a cross-cut was driven northerly and easterly, nearly along the line of movement, several hundred feet, but without satisfactory result. There is reason to believe that this is the same slide that crosses the North Star vein, and displaces it, in the Buel mine.

The existing condition of affairs is, therefore, that all the ore in sight has been worked out, since the available ground between the incline and the fault would be very little on the next level. While exhausting the ore-ground the machinery was not sufficient to serve in the regular work of the mine and in further exploration at the same time; thus, without reserves for the future, and now without funds, the mine has suspended operations. The incline to the first level is in good order. Below that point the mine is full of water. The machinery at the shaft consists of a small engine, a six-inch cylinder, driving friction-gear for hoisting, and working a small pump.

According to the returns of the assessor for the county this mine produced, from June 30, 1865, to June 30, 1867, a little over 2,000 tons of ore, yielding about $250,000 in coin, and from June 30, 1867, to June 30, 1868, 113 tons, yielding about $20,000 in currency.

GREAT EASTERN.—The Great Eastern is another formerly productive but now idle mine. It is situated considerably east or southeast of the main group of mines on Lander Hill. It was worked to the depth of 300 or 400 feet by means of an incline and, subsequently, a vertical shaft, the latter being equipped with good hoisting and pumping machinery. The work showed the ore to be essentially in one course or body, beginning about 100 feet from the surface and being about 160 feet in its longest direction, dipping with the vein, and 140 feet in horizontal measurement. The ore was of excellent quality, having the general characteristics already described. It yielded about 1,000 tons, giving $250,000. At the time of suspension of operations the expenditures for mining, equipment, and exploration were about $70,000 in excess of the pro-

duct. At the bottom of the vertical shaft, 320 feet deep, a cross-cut, at right-angles to the general course of the veins, had been run in each direction, having an aggregate length of over 1,000 feet; one end of this cross-cut is 500 feet vertically below the surface. Excepting the vein worked by the company, this cross-cut is said to have developed nothing important. The hoisting machinery has been sold since the suspension of mining operations, and removed to a mine in the eastern part of the State.

WHITLATCH UNION.—The Whitlach Union, on Union Hill, produced in the early days of its development, considerable bullion, amounting to about $45,000, coin, since June 30, 1865, according to the returns of the assessor. The vein is large, strong, and very well defined, but is faulted in manner similar to that shown in the section of the Savage mine, so that the ore-ground of the mine is bounded on the one side by the fault, cutting it off in depth, on the other side by the boundary line of the property, leaving a triangular-shaped piece of vein about 200 feet in length at surface and the same in depth, measured on the dip of the ledge at the boundary line. All attempts to recover the vein have so far been fruitless and the property has been idle a long time. Its neighbor, the Camargo, owns the continuation of the vein in the undisturbed part, but the ground is less rich, and although worked to some depth its operations have been suspended. A large quantity of low-grade ore is thought to be available in the mine.

YANKEE BLADE.—This is the most developed and probably one of the most promising of a group of mines opened in the so-called Yankee Blade district, two or three miles north of Lander Hill. It is a strong, well-defined vein, trending generally northwest and southeast, though not without some irregularity in its course. The dip of the vein, so far as yet developed, is westerly, about 60° from the horizon; the width varies from six inches to two feet. The vein was opened several years since by an incline and a vertical shaft 150 feet deep, and explored, at that depth, for a distance of 500 feet or more, in the Yankee Blade mine, besides similar work in the neighboring mine on the same vein known as the Whitlatch Yankee Blade. Both mines were quite productive for a time, but, having exhausted the patience of their owners before reaching a self-supporting basis, work was suspended and they remained idle for a long time. In 1868 the development of the Yankee Blade mine was

resumed by a new company, called the American Mining Company, under the management of Mr. A. A. Curtis. The old works were re-opened and the explorations developed a good body of ore from which about $20,000 were obtained. It became necessary, however, to sink to a greater depth than had then been reached, and for this purpose a new shaft was located west of the outcrop, designed to strike the lode at 300 feet in depth. When visited by the writer in September, 1869, this work was in progress. The shaft had reached the depth above named without finding the vein, and a cross-cut was being carried eastward in search of it. The prospects of this enterprise seemed to be of a favorable character. The new shaft is 12 feet long by 4 feet wide in the clear; timbered with three-inch plank. It is divided into three compartments. It is well equipped with hoisting and pumping machinery; there are two engines, each having a cylinder of 12 inches diameter. One of these is for hoisting, in which friction-gear is employed; the other is for pumping, for which purpose there is a 10-inch force-pump. The engines are so placed as to do each other's work, if necessary. The cost of sinking this shaft to the depth of 302 feet was as follows:

| | Per foot. |
|---|---|
| In December, 1868, 71 feet, at | $23 75 |
| In January, 1869, 47 feet, at | 68 68 |
| In February, 1869, 49 feet, at | 77 04 |
| In March, 1869, 24 feet, at | 111 19 |
| In April, 1869, 32 feet, at | 99 10 |
| In June, 1869, 16 feet, at | 144 06 |
| In July, 1869, 33 feet, at | 102 00 |
| In August, 1869, 30 feet, at | 124 04 |

In the Yankee Blade district, in which the mines just referred to are situated, are many others, more or less developed, some of which have attracted much attention in earlier days, but owing to various circumstances have long since suspended work. In 1869 the mine just described was the only one at work. There are also several mills in the neighborhood, one of which, the Metacom, was employed by the Lane and Fuller company in working the ores of their mine, although several miles distant. The other mills were idle.

Mills and Milling.—The milling of the ores of this district is rendered costly by the necessity of roasting them with salt before they can be subjected to the amalgamation process. None of them are sufficiently "docile" to be treated successfully by the ordinary Washoe method of wet-crushing, but being combined intimately with antimony, sulphur, arsenic, lead, copper, zinc, and iron, require a method similar in its general features to that by which the first-class ores of the Comstock are treated. This condition and the high cost of mining exclude from profitable treatment all low-grade ores. It has been already shown that the mining of the ore, even on a comparatively large scale and under favorable circumstances, does not cost less than $45 or $50 per ton; and, allowing a milling cost of $35 per ton, it is clear that an ore must yield $80 or $85 in order to return the costs of extraction and milling alone; and until some successful means of concentrating the poorer ores are introduced, or cheaper methods of milling are made practicable, a large proportion of the ore raised to the surface, or at least made accessible for stoping in the mines, must remain unavailable.

In the immediate vicinity of the Austin mining region there are now six or seven mills, having in the aggregate about 75 or 80 stamps. They are all designed to run by steam-power, and are furnished with roasting furnaces and barrels or pans, chiefly the latter, for amalgamation. The milling capacity of the region is far in excess of the production of the mines. During the early summer of 1868 but one mill, the Manhattan, was running, treating its own ores and those of all the other producing mines. The Keystone, a fine mill of 20 stamps, had been running in the spring, but was destroyed by fire.

The Metacom mill, in the Yankee Blade district, has since resumed work, having been leased by the Lane and Fuller Company; not so much to supply a demand for increased milling capacity as to control the price of milling by competition with the Manhattan. This excess of milling power is chiefly due to the mistakes of those who in the earlier days of the development of the district greatly overestimated the capacity of the mines to supply ore. Many of the companies first engaged there in mining operations made the blunder so common in all such enterprises, of erecting a large and expensive mill long before proving the value of their mine, the result being that a large amount of capital is locked up in costly and idle establishments.

The following notes concerning the Manhattan mill and some of the details of its working methods will probably suffice to give an idea of the condition of the milling business about Austin.

The Manhattan mill has 20 stamps, 10 roasting furnaces, and 14 pans, capable of crushing, roasting, and amalgamating 20 tons of ore per day, or 600 tons per month, if fully employed. The process by which the ores are treated resembles in its general features that by which the first-class ores of the Comstock lode are reduced, which has been already described in a preceding chapter. The amalgamation, however, is performed at the Manhattan mill in pans, instead of barrels. The principal operations of the process are dry-crushing, roasting with salt in reverberatory furnaces, and amalgamation in pans. The ore is prepared for the stamps by a "Thunderbolt," or Gardner crusher. This is set up near the entrance to the mill, and reduces the larger pieces to fragments about the size of an egg. This crusher is less widely used than the Blake, though the manager of this mill expresses satisfaction with its operation. After being broken by the crusher the rock is thrown directly upon a drying floor which is about 8 feet wide by 16 feet long. This is constructed generally like that already described at Dall's mill, in Washoe Valley, except that the heat in this instance is provided by causing the flue, which leads from the roasting furnaces to the stack, to pass under the drying floor on its way. When thoroughly dried the rock is fed to the stamps. These are arranged in four batteries of five heads, weighing about 700 pounds, dropping 8 inches, 85 times per minute. The screens are of brass wire-cloth, with 40 meshes to the linear inch. The capacity of these stamps is about one ton per head in twenty-four hours. The batteries are inclosed in tight, wooden dust-chambers that are about 8 feet high, and having ample space for men to enter and shovel out the pulverized ore. A tramway is laid through the chambers so that a car may be filled in them and moved thence, on the track, to the roasting furnaces, discharging directly into the hopper through which the furnace is supplied.

The furnaces are ten in number; four of them, of more recent construction than the other six, are similar in most respects to those already described at Washoe. The older furnaces differ in their manner of discharge, having an aperture in the hearth, near the stirring door, which may be opened when

desired, and the roasted charge raked through it, falling into a vaulted space or chamber below the hearth, and thence removed to the cooling floor. The newer furnaces are discharged through a door in the side, opposite to the stirring door, and falling directly upon the cooling floor. The furnaces are built of common brick. The hearth is 9 feet wide and 11 feet long, composed of hard bricks laid on their edges and closely together. The furnaces are built in sets of two each, having their fireplaces at opposite ends and a common flue between them, which in the newer lot leads down under the floor and thus to the stack. The charge of one of these furnaces is about 1,000 pounds, which, if consisting of ores of most common occurrence in the district, requires about six hours' roasting. Twelve per cent. of salt is generally added to the charge, and usually nothing else. In most cases the salt is mixed with the ore in the hopper, and so enters the furnace with it; but if the ore contains a large amount of sulphur the salt is not added until the ore has been for some time subjected to the roasting process, that the sulphur may first be partially oxidized and the formation of sulphates commenced. During the roasting the charge is constantly stirred, and turned repeatedly. Three men for each furnace are required for this work every twenty-four hours. Two men for twenty-four hours, one each shift, can attend to the discharge of the ore for the whole number of furnaces. Each furnace consumes about seven-eighths of a cord of wood per day. After being discharged and cooled the ore is taken to the pans for amalgamation. The pans, fourteen in number, are known as the Varney Pan, but they are made of wood. The flat bottom is furnished with dies of cast iron, and the iron muller, which is a flat, circular disk, is caused to revolve by machinery similar to that which has been described already in the chapter referring to Washoe processes.

The charge for each pan is 800 or 1,000 pounds. It is put into the pan with sufficient water to bring the pulp to the desired consistency. The muller is caused to revolve at the rate of 42 revolutions per minute. The muller does not need shoes, as no more grinding is necessary than to break up the lumps formed by caking in the furnaces; it revolves as an agitator, or stirrer, to keep the material in constant circulation, and is hardly suffered to touch the bottom. The iron of the muller serves as a chemical agent in the same manner as that which is put into the barrels, where these are in use, and the duration of the

muller in this process seldom exceeds six months, and sometimes is only three. The charge is worked six hours. Quicksilver is not generally supplied to the pan until after the charge has been working some time, so that the metallic chlorides may be decomposed by the iron, rather than at the expense of the quicksilver. The quantity employed is adapted to the richness of the ore. For ores worth $200 per ton, 250 pounds of quicksilver are used, which quantity is increased with ores of greater value. After six hours' treatment in the pan the charge is passed into the settler or separator. This is generally like those already described, and serves a similar purpose. The pulp is thinned and cooled by the addition of water, and gently agitated by a muller which revolves slowly, carrying wooden shoes, or stirrers. The fluid amalgam, collected in the settlers, is strained, and the solid portion retorted. The amalgam that collects on the mullers of the pans is removed from time to time, cleaned up in a small iron pan, and likewise retorted. About one-fifth part of the amalgam obtained from the pans and settlers is bullion, which is melted and run into bars for shipment. The bullion is usually $\frac{820}{1000}$ to $\frac{840}{1000}$ fine. It contains no gold. The impurity is chiefly copper. The retorting furnace is similar to that which has been already described. The loss in quicksilver in this mill is stated at one pound and a half per ton of ore worked.

The yield obtained from the ore is from 85 to 90, and sometimes a still higher percentage, of the assay value.

The power for driving the machinery of the mill is furnished by a steam-engine, horizontal cylinder, 42 inches in diameter and 18 inches stroke, to which two tubular boilers, 50 inches in diameter, supply steam, They consume about six cords of wood per day. The total consumption of wood per day for the mill, including steam, roasting furnaces, retorts, &c., is about 18 cords. It costs from $9 50 to $10 per cord.

The men employed during a day of twenty-four hours, two shifts, are as follows:

| | |
|---|---|
| Foremen, one each shift | 2 |
| Mechanics | 2 |
| At the rock-breaker and drying-floor, three by day, two by night | 5 |
| At the batteries | 3 |
| Supplying ore from the batteries to the furnaces | 3 |

| | |
|---|---|
| Furnace tenders, three at each of the furnaces | 30 |
| Coolers, attending to the discharge and cooling of the ore | 2 |
| Panmen | 4 |
| Retorting | 1 |
| Engineers | 2 |
| Wood-passers | 3 |
| | 57 |

The cost of the above labor is $3 50 to $4 per day, excepting that of the foremen, engineers, and mechanics, who receive more. The costs of working, per ton, are indicated by the following statement, which expresses the average for six months, from June to November, 1868. It is hardly necessary to observe that the costs will vary considerably, increasing very much if the quantity of ore worked be diminished, since a certain portion of the current expense must remain the same, whether the number of tons treated be great or small. Thus in March, 1868, when 278 tons of ore were worked, the cost per ton was $47 84. In the following month, working 462 tons, the cost per ton was $41 45. From June to November, 1868, the quantity worked was 3,005 tons, or about 500 tons per month. The details of cost were as follows:

| | |
|---|---|
| For labor | $13 99 |
| For fuel, ($10 per cord) | 8 83 |
| For supplies | 1 75 |
| For quicksilver | 1 09 |
| For salt, (two cents per pound) | 4 41 |
| For official labor | 1 57 |
| For castings | 3 21 |
| For hauling ore and fuel | 1 41 |
| | 36 26 |

The average in the following six months was $34 49 per ton.

The custom price for milling ores from other mines than those of the Manhattan company has been, until lately, $45 per ton, the mill guaranteeing

a return of 80 per cent. of the assay value. In the summer of 1869 the price was reduced, partly owing to the competing influence of the Metacom mill, to $35 per ton, with a return to the customer of 85 per cent. of the assay value. It will be observed that the cost of working, at its lowest figure, is but a trifle less, and is usually greater, than the custom price. The mill, however, still has a margin of profit, under favorable circumstances, as the yield of the ore often exceeds 85 per cent. of the assay value.

The yield of the ores of the Manhattan mine, from September 30, 1866, to January 1, 1868, varied from $111 24 to $255 77 per ton, coin value; the average for 2,410 tons amounting to $186. From June, 1868, to August, 1869, inclusive, the number of tons of ore worked in the Manhattan mill, produced by the Manhattan mine, was 2,087, having an average assay value of $150 88, coin, yielding an average return of $133 44 per ton, or 88.44 per cent. of the assay value. During the same period, that is, from June, 1868, to August, 1869, inclusive, the total number of tons of ore worked in the same mill, including the product of the Manhattan mine, with custom ores produced in other mines of the vicinity, was 5,745, having an average assay value of $247 99, and yielding an average return of $217 31 per ton, or 87.63 per cent. of the assay value.

The Metacom mill, which was engaged, in the summer of 1869, in working the ores of the Buel North Star, or Lane and Fuller Company, is situated three or four miles from Austin. The process employed is the same, in its essential features, as that already described, except that barrels are used instead of pans for amalgamation of the pulp. The mill has 10 stamps, weighing 900 or 1,000 pounds each. They drop 8 inches, 95 times per minute, being lifted by a single-armed cam. The capacity of the whole battery is eight tons per day.

There are four roasting furnaces, like those already described. The ore contains a good deal of lead and zinc, and requires very gradual roasting, involving the necessity of longer time than where these metals are less abundant. Each charge of 1,000 pounds is in the furnace about eight hours, giving a total capacity, for the four furnaces, of six tons per day. There are six barrels, each having a capacity of 1,000 pounds per charge. They resemble those, already described, at Dall's mill, but are moved by friction-gear,

which is said to be better than either cog-gearing or belting. The V-shaped friction-surface is cast in a rim that encircles the end of the barrel; the pinion, with corresponding surface, is fixed in a sliding pillow-block, which may easily be moved forward or backward, in order to be placed in or out of contact with the rim, and so cause the barrel to revolve or to stand still.

The mill, at the time referred to, was working 200 tons per month, of which the average yield was $170, coin.

Bullion Product of Austin Mines.—The bullion product of the country about Austin is not easily stated within close limits of accuracy. The accounts of the banks and express office frequently include lots of bullion from sources quite remote from Austin, such as Twin River, Belmont, and, formerly, White Pine.

In 1868 the shipment appears to have been as follows:

| | |
|---|---|
| From the Manhattan company | $1, 152, 576 75 |
| J. A. Paxton & Co., bankers, shipping bullion derived from many sources, including $96,711 28 from White Pine | 1, 070, 727 16 |
| National Bank | 514, 000 00 |
| | 2, 737, 303 91 |

During the first eight months of 1869 the shipment of bullion from Austin, most of which was produced in the immediate vicinity, was between $90,000 and $100,000 per month.

Outlying Districts.—The Toyabe range, of which the Austin mining region is the principal point of interest, has been explored for many miles along its course, from north to south. Extending in the last-named direction some 40 or 50 miles from Austin, and situated chiefly on the eastern slope of the range, there is a succession of mining districts, which, during the earlier days of their history, were regarded as very important. Considerable sums of money have been expended in their development, and several large and costly mills were built for the working of their ores. The value of many of these mines or districts was doubtless vastly overestimated, and the money spent upon them was wasted. Others have been shown by steady development to be rich and valuable mines, but few, if any, of these have been worked with profit, under the disadvantages of high cost of labor and materials, and the necessity of

large outlays for mining and milling equipment, involving, in some cases, great financial embarrassment. Under these and other hindrances to success nearly every mining enterprise in this section of country has been neglected during the past year or two, notwithstanding the fact that some of them, as, for example, the Murphy mine, had already produced a large amount of bullion.

BUCKEYE.—One of the most persistently worked mines, though on a limited scale of operations, is the Buckeye, situated in Summit Cañon, about 45 miles south of Austin. The vein on which this mine is located appears to be at the contact of limestone and slate. Its course is nearly north and south. The dip is not very regular; it is generally westward, at a high angle. The width of the vein varies from a narrow seam to four or five feet. The ore, a mixture of argentiferous galena, blende, and silver sulphurets, occurs in bunches or pockets, of irregular form and mode of distribution. Some of it is very rich, and various lots have been taken to Austin and worked at the Manhattan mill, yielding about $300 per ton. In August, 1869, a little over nine tons were thus worked, yielding, on the average, $283 52 per ton. Operations were still in progress at this mine at the last accounts. There is a large amount of ore on the surface, estimated to be worth $100 per ton, not rich enough to warrant expensive transportation to Austin and high prices for milling, which must be reserved for a mill nearer at hand.

MURPHY MINE.—The Murphy mine,[1] or, as it is sometimes called, the Twin River mine, because formerly the property of the Twin River Mining Company, is one of the best developed and most important mines in this part of the range; or, indeed, in Central Nevada. The mine is situated in Ophir Cañon, about two miles west of the opening of the cañon into Smoky Valley. The general course of the ledge is about north and south, crossing the cañon at nearly a right angle. Its dip is easterly, averaging about 45 degrees. It is inclosed in metamorphic rocks generally described as slates. The walls of the vein are very well defined, usually very smooth and carrying but little "gouge," or parting of clay, between them and the body of the vein. The fissure is filled with a hard, compact quartz, sometimes pure white, sometimes colored by oxide of iron; it varies in width from one or two feet, in "pinches," to ten or

[1] The writer is indebted to the courtesy of Mr. S. S. Robinson, formerly superintendent of the Murphy mine, for much information concerning its operations.

twelve feet, or even more, but averaging about eight feet. This quartz carries a pay-seam, or rich band, which seldom occupies the whole width of the vein, but has a variable thickness, between one and four feet, averaging perhaps two feet or little more. The seam sometimes follows the hanging, sometimes the foot-wall, or passes from one to the other, occupying in places the middle portion of the vein between its walls. Within this pay-seam the silver-bearing mineral occurs distributed in irregular, bunchy form, intimately mingled with the gangue of the hard, glassy quartz. It has but little, if any, of the banded structure of the Lander Hill veins, near Austin, and does not usually carry its valuable components densely concentrated in a seam of solid mineral, as those veins do. The silver-bearing portion of the ore consists chiefly of a fahlerz, an antimonial sulphuret, with which is associated at times some ruby silver, some fine-grained argentiferous galena, and considerable quantities of zincblende, which, according to Mr. Bessler, the former metallurgist of the works, carries silver to the extent sometimes of $600 to the ton. Some native silver also occurs. Iron pyrites is a frequent associate of the gangue; a fine-grained variety, especially, accompanies good pay-ore and is not an unwelcome feature in the vein. The length of the company's claim is 1,000 feet. Its southern boundary is at or just south of the bed of the creek that flows in the cañon. Extending thence to the northward, the surface along the line of the vein rises rapidly, reaching an altitude of 420 feet above the mouth of the shaft near the bed of the stream, in the distance of 1,000 feet, or at the northern boundary. The accompanying section, Fig. 4, on Plate XXVII, shows the manner in which the mine has been opened.

An incline shaft, *I*, having its mouth 60 feet north of the southern boundary, and a few feet above the bed of the stream, has been sunk in the plane of the ledge, but at such an angle with the direction of its dip that the horizontal distance between the incline and south boundary is increased 20 feet by every 60 feet sunk; the whole depth of the incline (not vertical) being 240 feet in June, 1868. At the mouth of the incline an adit, *A*, is driven into the hill, following the course of the ledge to the distance of nearly 300 feet, passing through irregular or scattered bodies of ore, of small importance, and finally losing the vein in ground that is much disturbed, probably by the fault that is clearly visible in the levels below.

Four levels have been driven from the shaft, the extent of which may be readily seen in the section; the character of the ground passed through is also partly indicated, the shaded portions representing the stopes. It will be seen that the vein in the northern part of the work is cut off by a fault, *f, f.* This is occasioned by a cross-vein, or slide, having a nearly east and west course, and dipping north at an angle of about 50°. This slide is encountered in the 10-fathom level at a distance of 310 feet, and in the 20-fathom level 340 feet north of the incline; the distance between the incline and the slide thus gaining on each successive level in depth. On the 10-fathom level the vein is cut off abruptly by the slide, beyond which a wide belt of soft, clayey, altered rock was cut through. A small seam, having the general course of the main vein, was followed for about 100 feet and a cross-cut driven from that point east, but without satisfactory result. Attempts have also been made on the same level to find the vein in the western country-rock, and were in progress in the summer of 1868, but had not reached anything definite when the operations of the mine were suspended, for reasons mentioned below.

The distribution of ore in the vein is shown by these developments to be variable, rich courses of ore alternating with ground, if not barren, at least too poor to pay at present rates. The richest portion of the mine was between the third and fourth levels, directly under the slide. Immediately above the third level the ground for its entire length was rich enough to stope, but courses or chimneys of ore, richer than the surrounding portions, were perceptible. These courses have a northerly dip, and extend for 100 feet or more in horizontal measurement. The most remarkable was that just under and dipping with the slide, where the vein was very large and rich, the pay-seam in places filling the entire width of the vein, about 8 feet, and carrying ore of a very high grade. Two others, of less importance, occurred further south, one near the incline and one about 100 to 150 feet north of it; both being in the neighborhood of, and coinciding in direction with, the so-called "floors" in the vein, or cross-seams, traversing the vein distinctly, but not occasioning any fault or displacement. The general direction and location of these "floors," as indicated by Mr. Richards, captain of the mine, are shown in the section by the lines *s s.*

The costs of working the mine, the details of which are given further on,

are greatly enhanced by the extreme hardness of the rock, requiring a large outlay in steel, powder, and muscle. Steel of 1⅛ inches diameter is used for drills, and it is not uncommon to dull 30 of them in boring a two-foot hole. Two men are required constantly to sharpen the tools for 44 miners.

The walls of the vein, although pretty firm, require some heavy timbering. When the pay-seam is next the hanging-wall it is stoped out, leaving the underlying portion of the vein in place; but when it is in the foot-wall the hanging portion of the vein must usually be taken with it, as, if left, it would soon drop from the hanging wall. This sometimes involves the use of heavy timbering. Fortunately, though somewhat distant and sparsely scattered, the supply of timber is sufficient for years to come. Stulls, from one to two feet in diameter and ten to twelve feet long, cost from $3 50 to $5 apiece. These are commonly placed six feet apart and a lagging of smaller stuff placed behind them.

In June, 1868, there were 44 miners employed, nearly one-half of whom were stoping. Including fillers, landers, rock-pickers, &c., the mining force was 70 men. At that time the mine was producing about 12 tons of milling ore per day, to obtain which some 50 tons of rock were mined and raised for assorting. Labor was then employed chiefly by the day at an average cost of $4, in coin, for miners. The machinery at the hoisting works at the mouth of the incline consists of an engine, having a cylinder of 12 inches diameter and 24 inches stroke, driving a winding wheel by friction-gear and a pump by means of toothed pinion and wheel. The pump is an eight-inch draw-lift, raising water from the bottom of the mine, being extended as the depth of the incline increases, in manner similar to that already described in a foregoing chapter. The mine is very wet and the pump must be constantly employed while mining work is in progress.

The company own a large and costly mill, which is situated in the neighborhood of the mouth of the incline, only a few hundred feet distant, so that the ore, after necessary assortment, is delivered at very little expense. The mill comprises 20 stamps, 8 roasting furnaces, and 8 amalgamating pans, and 5 settlers or separators, besides retorting, melting, and assaying departments that are furnished with all the necessary appurtenances of the business.

The method of treatment to which the ore is subjected does not differ

essentially from that already described in this chapter, employed at the Manhattan mill, in Austin, and need not be repeated here. The following notes concerning this department will suffice.

The mill is furnished with a Blake's rock-breaker. The stamps, 20 in number, weigh 800 pounds each; they drop 9 inches, 70 times per minute. Screens of wire-cloth, having 60 meshes to the linear inch, are used, the discharge being on both sides of the battery. The capacity of the stamps is 20 tons per day. The roasting furnaces are the same, in all essential points, as those in use at Dall's mill, in Washoe, described elsewhere. The amalgamation of the roasted ore is performed in pans, as at the Manhattan mill. The bullion produced is between 700 and 800 fine, the impurity being chiefly copper. The average yield of the ore during the year 1867 was $111. The ore assays from $130 to $150; of which value 80 or 85 per cent. is obtained in the mill. Pan-tailings assay from $12 to $14 per ton.

The machinery is driven by an engine of which the cylinder is 18 inches in diameter and 36 inches stroke; for which steam is furnished by two tubular boilers, 15 feet long, consuming about 6 cords of wood per day.

| | |
|---|---|
| The ordinary costs of reduction of the ore during 1867, for 3,847½ tons were | $35 36 |
| And for repairs, per ton | 5 19 |
| Equal to | 40 55 |

Of which the details are given below.

The following statements show the working expenses of this mine for the year 1867, including mining, milling, and general costs for the whole business.

*Statement of Mining Cost for the year ending December 31, 1867.*

| Labor of miners. | No. of fathoms stoped. | | No. of feet drifted. | No. feet sunk. | | Rate per fathom. | Rate per foot. | | | Cost of stoping. | Cost of drifting. | Cost of sinking. | | Total cost. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Shafts. | Winzes. | | Drifting. | Sinking. | | | | Shafts. | Winzes. | |
| | | | | | | | | Shafts. | Winzes. | | | | | |
| | *Fms.* | *Feet.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | | | | | | | | | |
| Stoping north of shaft, 10-fathom level | 92 | 129 | | | | $35 58 | | | | $3,294 22 | | | | |
| Stoping north No. 1 winze, 10-fathom level | 10 | 177 | | | | 79 06 | | | | 855 43 | | | | |
| Stoping south No 1 winze, 10-fathom level | 3 | 108 | | | | 64 91 | | | | 227 17 | | | | |
| Stoping south of shaft, 20-fathom level | 38 | 108 | | | | 64 87 | | | | 2,497 56 | | | | |
| Stoping north of shaft, 20-fathom level | 111 | 69 | | | | 42 48 | | | | 4,728 77 | | | | |
| Stoping north and south No. 1 winze, 20-fathom level. | 408 | 17 | | | | 38 78 | | | | 15,824 81 | | | | |
| Blasting down side in adit level | 2 | | | | | 72 75 | | | | 145 50 | | | | |
| Blasting down side in 10-fathom level | 1 | 144 | | | | 81 52 | | | | 135 87 | | | | |
| Blasting down side in 20-fathom level | 3 | | | | | 88 92 | | | | 266 75 | | | | |
| Blasting down side in shaft | 1 | 108 | | | | 81 00 | | | | 121 50 | | | | |
| Blasting in open cut | 6 | | | | | 46 00 | | | | 276 00 | | | | |
| Drifting north of shaft, 10-fathom level | | | 129 6 | | | | $34 30 | | | | $4,441 26 | | | |
| Drifting north of shaft, 20-fathom level | | | 341 6 | | | | 29 59 | | | | 10,103 98 | | | |
| Drifting south of shaft, 20-fathom level | | | 13 | | | | 32 42 | | | | 421 50 | | | |
| Drifting north of shaft, 30-fathom level | | | 54 | | | | 36 97 | | | | 1,996 13 | | | |
| Drifting south of shaft, 30-fathom level | | | 23 | | | | 28 11 | | | | 646 57 | | | |
| Drifting crosscut west from adit level | | | 13 | | | | 14 69 | | | | 191 00 | | | |
| Sinking incline shaft | | | | 70 | | | | $59 53 | | | | $4,166 79 | | |
| Raising air shaft from adit level | | | | 8 | | | | 11 84 | | | | 94 70 | | |
| Sinking No. 1 winze under 10-fathom level | | | | | 25 | | | | $46 94 | | | | $1,173 50 | |
| Sinking No. 1 winze under 20-fathom level | | | | | 38 6 | | | | 42 64 | | | | 1,641 45 | |
| Sinking No. 2 winze under 20-fathom-level | | | | | 24 | | | | 24 37 | | | | 584 93 | |
| | 678 | 212 | 574 | 78 | 87 6 | 41 79 | 31 01 | 54 63 | 38 86 | 28,373 58 | 17,800 44 | 4,261 49 | 3,399 88 | $53,835 39 |

| | | |
|---|---|---|
| Brought down | $53,835 39 | |
| Mining captains and timbermen | 6,868 53 | |
| Wheelers, trammers, and sorters under ground, and landers | 12,401 60 | |
| Cost of raising ore and water | 9,658 24 | |
| Cost of sharpening drills, picks, &c. | 10,493 05 | |
| All other blacksmith work | 1,316 27 | |
| Carpenter work | 1,222 49 | |
| Timbers, lagging, lumber, and other materials | 9,187 56 | |
| Pump-pipe and rods, labor and repairs | 1,326 88 | |
| | | $106,310 01 |
| *Assorting and hauling ore.* | | |
| Labor in assorting 3,837½ tons ore | 5,954 00 | |
| Materials used | 41 31 | |
| Hauling 3,737½ tons ore to mill | 477 09 | |
| Cost of repairs to cars and wagons | 38 75 | |
| | | 6,511 15 |
| Reduction cost, as per following statements of current costs and repairs | | 155,999 74 |
| *Bullion charges.* | | |
| Transportation | 3,209 90 | |
| Charges on sales to Austin bankers | 10,232 06 | |
| Melting, assaying, and United States tax | 5,308 30 | |
| | | 18,750 26 |
| *General expense.* | | |
| Expense of agents, clerk, and superintendence | 11,068 76 | |
| Other general expenses, exchange, insurance, State taxes, and incidentals | 23,231 61 | |
| | | 34,300 37 |
| | | 321,871 53 |

*Statement of Reduction Cost for*

| 1867. | Cost of superintendent. | Cost of engineers and firemen. | Cost of rock-breaker tenders. | Cost of stamp tenders. | Cost of tending dry kiln, tramming to furnaces and pans, and cooling ore. | Cost of furnacemen. | Cost of amalgamators and helpers. | Cost of retorter and smelter. | Cost of weighing ore and cleaning flues. |
|---|---|---|---|---|---|---|---|---|---|
| January | $422 09 | $613 00 | $332 00 | $270 00 | $918 00 | $2,928 50 | $403 00 | $216 50 | . . |
| February | 400 60 | 536 00 | 220 00 | 255 00 | 681 00 | 2,648 50 | 230 00 | 140 00 | . . |
| March | 408 36 | 635 00 | 246 00 | 282 50 | 847 00 | 2,722 50 | 429 00 | 252 50 | . . |
| April | 418 38 | 652 00 | 270 00 | 295 00 | 667 00 | 2,483 00 | 399 50 | 274 00 | . . |
| May | 396 16 | 646 00 | 214 00 | 232 50 | 668 00 | 1,932 00 | 343 75 | 155 00 | . . |
| June | 413 06 | 661 00 | 204 00 | 237 50 | 603 00 | 1,667 00 | 400 50 | 139 00 | . . |
| July | 396 59 | 623 00 | 170 00 | 195 00 | 563 00 | 1,772 00 | 285 00 | 253 50 | . . |
| August | 396 83 | 636 00 | 121 00 | 306 25 | 649 00 | 2,353 00 | 317 50 | 297 25 | . . |
| September | 428 92 | 508 25 | 112 00 | 227 50 | 426 00 | 1,741 00 | 271 25 | 288 00 | . . |
| October | 418 16 | 589 25 | 128 00 | 315 00 | 505 00 | 2,257 00 | 292 50 | 275 25 | $60 00 |
| November | 422 79 | 583 37 | 131 00 | 297 00 | 957 00 | 3,086 00 | 300 00 | 272 25 | 100 00 |
| December | 433 28 | 559 37 | 107 00 | 253 75 | 770 00 | 2,342 25 | 291 50 | 274 25 | 222 00 |
| | 4,955 22 | 7,242 24 | 2,255 00 | 3,167 00 | 8,254 00 | 27,632 75 | 3,963 50 | 2,837 50 | 382 00 |

REPAIRS.

| 1867. | Cost of labor repairing machinery. | Cost of materials for repairs, (new castings.) | Total cost of repairs. | Number of days mill in operation. |
|---|---|---|---|---|
| January | $802 14 | $1,144 52 | $1,946 66 | 31 |
| February | 692 10 | 1,117 02 | 1,809 12 | 24 |
| March | 460 87 | 2,522 17 | 2,983 04 | 26½ |
| April | 560 25 | 958 02 | 1,518 27 | 30 |
| May | 355 39 | 805 80 | 1,161 19 | 31 |
| June | 204 06 | 412 39 | 616 45 | 30 |
| July | 221 77 | 811 43 | 1,033 20 | 31 |
| August | 530 16 | 816 68 | 1,346 84 | 31 |
| September | 418 28 | 325 65 | 743 93 | 22 |
| October | 491 54 | 2,380 84 | 2,872 38 | *a* 25¼ |
| November | 558 42 | 1,066 55 | 1,624 97 | 30 |
| December | 949 52 | 1,350 40 | 2,299 92 | 27 |
| | 6,244 50 | 13,711 47 | 19,955 97 | 338¾ |

*a*. 10 tons and 1,406 pounds additional

Ordinary expenses of reduction, $136,043 77. Or, $35 36 per ton of ore.
Expenses for repairs, $19,955 97. Or, $5 19 per ton of ore.
Total expenses, $155,999 74. Or, $40 55 per ton of ore.

*the year ending December* 31, 1867.

| WOOD. | | | | Cost of salt. | Cost of quicksilver. | Cost of oil, tallow, &c., used on machinery. | Cost of lighting mill. | Cost of charcoal, assay material, and all other materials and tools. | Total running expense. |
|---|---|---|---|---|---|---|---|---|---|
| Engine. | | Furnaces. | | | | | | | |
| Cords. | Cost. | Cords. | Cost. | | | | | | |
| 157¾ | $2,377 03 | 215¼ | $2,473 49 | $2,042 02 | $704 69 | $172 50 | $148 35 | $576 99 | $14,598 16 |
| 164½ | 2,340 94 | 168 | 1,628 87 | 1,539 30 | 621 73 | 198 20 | 120 30 | 383 17 | 11,943 61 |
| 187⅝ | 2,568 45 | 179½ | 2,090 45 | 1,344 00 | 569 84 | 126 00 | 127 80 | 400 48 | 13,049 88 |
| 157⅝ | 1,603 51 | 169½ | 1,677 63 | 1,158 50 | 427 48 | 165 45 | 89 00 | 418 98 | 10,999 43 |
| 186½ | 1,914 28 | 140¼ | 1,545 72 | 847 00 | 339 84 | 100 95 | 31 30 | 297 05 | 9,663 55 |
| 182 | 1,826 17 | 146¾ | 1,494 05 | 764 74 | 317 52 | 132 12 | 40 42 | 305 02 | 9,205 10 |
| 175 | 1,874 14 | 145 | 1,435 50 | 878 50 | 364 19 | 147 05 | 69 75 | 340 37 | 9,367 59 |
| 204⅝ | 2,163 10 | 175⅜ | 1,682 37 | 1,130 50 | 333 02 | 137 85 | 88 09 | 447 84 | 11,057 60 |
| 167⅜ | 1,704 55 | 135 | 1,303 00 | 1,053 00 | 228 67 | 99 43 | 66 98 | 284 73 | 8,743 28 |
| 190½ | 2,116 37 | 161⅞ | 1,585 70 | 1,430 18 | 281 77 | 175 62 | 104 58 | 621 19 | 11,155 57 |
| 217½ | 2,260 16 | 226¾ | 2,093 81 | 2,203 44 | 512 78 | 113 48 | 152 91 | 615 10 | 14,101 09 |
| 247⅞ | 2,608 87 | 182¾ | 1,699 13 | 2,155 70 | - - - | 126 75 | 176 68 | 566 50 | 12,587 03 |
| 2,238⅞ | 25,357 57 | 2,046 | 20,709 72 | 16,546 88 | 4,701 53 | 1,695 40 | 1,214 16 | 5,257 42 | 136,471 89 |
| 10 tons 1,406 pounds worked for Buckeye Mining Company in October, at $40 . . . . . . . . . | | | | | | | | | 428 12 |
| | | | | | | | | | 136,043 77 |

RESULTS.

| Number of tons stamped. | Per cent. of stamps run per day. | Average number of tons stamped per head per day. | Number of tons roasted. | Number of tons amalgamated. | Number of tons stamped and amalgamated per cord of wood. | Number of tons roasted per cord of wood. |
|---|---|---|---|---|---|---|
| 404 | 85. | 0.766 | 429 | 417 | 2.60 | 1.99 |
| 378½ | 85.6 | 0.921 | 366½ | 354½ | 2.23 | 2.18 |
| 384 | 77. | 0.941 | 384 | 390 | 2.065 | 2.14 |
| 327 | 63.35 | 0.861 | 331 | 351 | 2.15 | 1.95 |
| 242 | 50. | 0.781 | 242 | 236 | 1.28 | 1.72 |
| 212½ | 46.35 | 0.764 | 214½ | 218½ | 1.21 | 1.46 |
| 253 | 47.55 | 0.858 | 251 | 249 | 1.43 | 1.73 |
| 317 | 46.77 | 1.09 | 323 | 325 | 1.57 | 1.84 |
| 238 | 42.25 | 1.28 | 234 | 226 | 1.385 | 1.73 |
| 276 | 55.45 | 1.02 | 278 | 278½ | 1.51 | 1.78 |
| 458½ | 81. | 0.943 | 460½ | 460½ | 2.115 | 2.03 |
| 347 | 72. | 0.890 | 330 | 341½ | 1.39 | 1.81 |
| 3,837½ | 61.6 | 0.922 | 3,843½ | 3,847½ | 1.72 | 1.88 |

worked for Buckeye Mining Company.

Number of ounces of bullion produced, 445,372½.
Value of product, $427,227 69.
Average value of ore per ton, $111 04.

| | | |
|---|---|---|
| During the period to which the foregoing statements apply the production of bullion amounted to | | $427, 227 67 |
| From which deducting the costs at mine, as already shown | $321, 871 51 | |
| Expenses in New York $7,140 60, currency, equal in gold at $1 40 to | 5, 100 00 | |
| | | 326, 971 51 |
| Showing a profit on the year's work of | | 100, 256 16 |

The total product of the mine from the date of organization to the time of its suspension of work in the summer of 1868 is shown by the company's books to be about $700,000. Notwithstanding this large production, the greater portion of which was obtained at a fair profit above the actual running expenses, the company has suffered great pecuniary embarrassment, and, late in 1868, became bankrupt. This last step appears to have been due more to the lack of a proper understanding or of harmonious co-operation in the management of the company's affairs than to any unfavorable developments of the mine; although, just at that time, the amount of ore in sight was less than usual. The rich ground opened for stoping had been exhausted, and further work was necessary in order to reach the deposits believed to be accessible. The chief cause of the embarrassment, it is said, was the large outlay made at the beginning of operations, in costly surface improvements, involving not only all the money advanced by the stockholders, but all the profits of the mine beside. The mill alone cost $183,000. Meantime the mine was never opened sufficiently in advance of the demands of the mill, so that the latter was often employed to only a part of its full capacity, thereby enhancing the costs of treatment; and it was deemed necessary in the summer of 1868 to close the mill until the mine could be more extensively opened, and ground thus prepared for more economical operations. The production of bullion being thus suspended, a call upon the stockholders for further capital became necessary; but owing to the existing discouragement on their part or to a lack of a proper appreciation of the true condition of affairs, the assessments were not paid and the company became embarrassed. The property was attached

and all mining operations were suspended. The amount of indebtedness was comparatively small, not exceeding the actual value of the supplies and material on hand and available for use; saying nothing of the mill, hoisting machinery and improvements that had cost about $250,000. In the summer of 1869 the property of the company was sold by the assignee, and was purchased by a new organization known as the "Cambridge Silver Mining Company." The new owners employed a small force in the autumn of last year in draining the mine and extending the explorations; but this work was shortly after suspended without obtaining definite results.

PHILADELPHIA OR SILVER BEND DISTRICT.—This district is situated in the range of mountains next east of the Toyabe, and is about 85 or 90 miles south from Austin. The following notes on the geology of the region are furnished by Mr. S. F. Emmons.

GEOLOGY.—The range of mountains parallel to the Toyabe, which forms the eastern border of Smoky Valley, is called the Smoky Valley Range. At the point where the overland stage-road crosses it, at its northern end, it is composed of rhyolite; from here south to Charlotte's Pass, which is about opposite Ophir Cañon, it is a low, flat-topped ridge, whose form and general appearance would suggest a predominance of volcanic rocks in its formation. At Charlotte's Pass, through which runs the stage-road from Austin to Belmont, the entire mass of the range is rhyolite and rhyolitic breccia. Out of the ravine, on the western side of this pass, rises a conical peak of reddish-white porphyritic rhyolite, which has a remarkably regular columnar structure. The upper part of the ridge is of rhyolitic breccia, out of which this long ravine has been gullied; while on the eastern slope are strata of rhyolite, dipping east at an angle of 30°, of highly colored varieties—white, purple, yellow, brick-red, and reddish-brown. South of Charlotte's Pass extends a group of high, smooth-topped peaks, whose summits carry snow until the middle of the summer. These are probably composed of limestone and metamorphic slates; on their eastern flanks, however, are several outcrops of rhyolite. The southern point of this group, some 30 miles south of Charlotte's Pass, is the Granite Mountain, from which runs out the spur or ridge to the southeast, where the mines of this district are situated. This ridge separates Monitor Valley on the north

from Ralston Valley on the south, being at its highest point not more than a thousand feet above these valleys.

The town of Belmont, which is 30¾ miles in a straight line, south 51° east, from the mouth of Ophir Cañon, is situated in a ravine on the southern slope of this ridge, at an elevation of 7,393 feet above sea-level. The Granite Mountain is a triple-pointed peak, having an elevation of between 9,000 and 10,000 feet; its mass is, as its name indicates, of granite, whose weathered surfaces are somewhat rounded by the action of the atmosphere, but not decomposed to as great an extent as that in the immediate vicinity of Belmont. From it extends down to the southeast, toward Belmont, a long, continuous spur of granite, on whose northern side are metamorphic slates dipping to the northeast; at the line of contact are nodular shales having a bronze color and a curiously wavy or rippled surface, as if rounded pebbles were crushed in between the layers. Beyond this belt of slates are limestone strata, conforming with it in dip and strike; the line of contact between the slates and limestone can be traced for miles down the ravine on the north of this spur. To the south of the spur, on its slope toward Ralston Valley, and west from Belmont, is a very picturesque little tract of country, still well wooded, as are most of the hills around Belmont, where the granite, here easily decomposed by the atmospheric agents, has been worn into various curious shapes—castellated peaks and table-topped mounds; columns consisting of blocks standing one upon the other, originally square, but now so rounded that they seem boulders piled up by man's hand, and in imminent danger of falling off. In all these ravines are small springs and rivulets, around which are small extents of green grass.

Belmont itself is built over the line of contact between the granite and the slates; the foot-hills below it and the crest and southern slope of the ridge to the south are all of granite, a coarse-grained, easily decomposed rock, containing large twin crystals of orthoclase, which remain after the surrounding mass has crumbled away. In this granite are frequent dikes of white fine-grained granulitic rock, composed mostly of quartz and feldspar. To the east of Belmont, quartzite is the contact rock next the granite on the north, beyond which are metamorphic slates, while the foot-hills of the Smoky Valley Range, still further north, are composed of strata of blue limestone, in which were

found no fossils; they are probably of the same age with the Toyabe limestone.

To the east of Belmont, and beyond a hill of granite which rises immediately above it, is Highbridge Hill, in which are the principal veins of the district. This hill is composed of quartzites and slates, and in the ravine which separates it from the main granite ridge south is the line of contact between the quartzite and granite. In this hill are two series of veins, the one in the quartzites, the other in the slates, both generally conformable in dip and strike with the formation; having a strike north 15° west and a dip of about 45° to the north and east. The former includes the El Dorado, Atlanta, Galvin, Arizona, and other ledges, which extend from the southwest extremity of the hill up over its main crest. The second series includes the famous Highbridge and Transylvania veins, which occur low down on the northeast slope of the hill. These two are probably part of the same ledge, though the connection between them has not yet been traced, and the existence of a fault would probably be necessary to explain the relatively lower position of the latter. This belt of slates and quartzites seems to contain the most of the veins of the district, though none have been developed to any extent outside of Highbridge Hill. In the limestone a few miles northwest of Belmont is the Silver Champion, which has produced some rich ore, and various other undeveloped ledges. Along the northern slope of the granite ridge south of Highbridge are some small veins, on the contact line with the granite. This body of granite seems to be cut off by a break in the ridge some five miles southwest of Belmont, while the slates extend further on in the ridge which connects with the Monitor Range. The vein southwest from here extends over a wide extent of country, whose hills are mostly low, table-shaped, volcanic ridges, which give it a very desolate and forbidding aspect.

The large mill of the Combination Company is situated just east from Belmont and north from Highbridge Hill. Near this the white quartzite crops out very distinctly, and beyond it are the limestones; out of these rise, just north of the mill, on the very edge of the valley plain, three peculiar-looking hills, composed of a grayish volcanic pearlite, very much decomposed, which are probably of rhyolitic origin, as this is the only volcanic rock found in this range. It occurs in the eastern foot-hills of the Smoky Valley Mountains, about

five miles north of Belmont. The section No. 5 on Plate XXVI gives a profile of Highbridge Hill and the granite hill southwest of it, on a true scale. The section is made on a line north 58° east. The quartzites exposed here are probably the product of a local metamorphism, and do not seem to correspond to the quartzites of Summit Cañon in the Toyabe Range.

Mining Developments in Philadelphia District.—The town of Belmont is the center of a mining region of considerable importance, situated 85 or 90 miles from Austin, in a south-southeasterly direction. It is in the "Smoky Range" of mountains, next east of the Toyabe, separated from the latter by Smoky Valley. The district of most importance, judging by developments thus far made, is called the "Philadelphia," or, sometimes, the "Silver Bend." It is in this district that the town of Belmont is located; and the first important discoveries of silver-bearing lodes, in this vicinity, were made near the site of that town in 1865. A small spur of the main range branches off here to the southeast, and it is on the eastern slope of this spur that the principal mining developments have been made. The best developed and most promising veins are inclosed within a belt of metamorphic rocks, resting on granite, which here forms the central portion of the range. These metamorphic rocks, where in contact with the granite, are frequently highly altered, and may come under the general name of quartzite; while, a little more remote from the granite, further to the eastward, and overlying the quartzite, is a belt of slates, striking nearly north and south, or north a little westerly, and dipping to the eastward, from 30° to 50°. This belt of slate is probably not less than a half or three-fourths of a mile in width, measured from west to east, and is the outcropping rock of the hillside, from its contact with the quartzite or granite down to where the slope merges into the plain of Monitor Valley. The ledge, or vein, on which the largest amount of work has been expended, and by reason of which the district has become widely known, is the Highbridge or Transylvania. It is inclosed within the slates, conformably with them, having a course north 15° west, true, and dipping to the eastward generally, at an angle of about 30°, but sometimes much steeper, especially where the ground has been much disturbed, as in the Belmont and Combination mines, where the dip varies between 60° and 90°. The outcrop has been traced, for a distance of many hundred feet, along the side of

the hill, and, perhaps, 200 or 300 feet above the level of the valley. On this vein are located the mines of the Combination Gold and Silver Mining Company, Belmont Silver Mining Company, the Elmore—a short claim—and the Silver Bend Company. The mines located by these several companies were not at first generally believed to be on one and the same ledge, and a difference of opinion still exists among interested parties, but the developments show pretty clearly that the ledge is one that has been faulted on the Belmont property, the southern extension of it having been thrown to the eastward about 150 feet. The Belmont claim is, therefore, in two parts, the northern claim being on the so-called Highbridge, unquestionably the continuation of the vein claimed by its northern neighbor—the Combination Company; while the southern portion, a little further east, but having similar course, is located on what is termed the Transylvania, which is, without doubt, identical with the vein of the Elmore and the Silver Bend, further south. The indications, both on the surface and underground, so far as opened, point clearly to the conclusion that these locations are all on one vein, known as the Highbridge, north of the fault or break, and as the Transylvania south of that point.

Combination.—The northernmost claim, on which any important work has been done, is that of the Combination, which is said to be 5,000 feet in length, although their explorations have been chiefly made within 400 or 500 feet of their south boundary, while the ground proved by actual developments to be productive was, at the date of the writer's visit, in the extreme southern portion of the claim, not exceeding 225 feet in length. The surface workings yielded largely in "chloride" ores, and the vein along the croppings, which was split into two or three branches, has been extensively wrought. In depth the vein has been opened from below by means of a tunnel driven in from the eastward, through the country-rock, located about 150 feet from the south boundary, 244 feet in length, and cutting the vein at 70 feet below the surface. Where cut by this tunnel the vein was poor, but a drift to the south about 30 feet encountered a good body of ore. From the end of the crosscut a winze was sunk, which also, at a depth of 60 feet, encountered the same body, which continued from this point down to the water level, 160 feet below surface. A vertical shaft, located east of the croppings on the surface,

has also been sunk, with the intention of cutting the vein in depth. At 90 feet depth it reached the water level, and at that point a cross-cut was driven to the vein, which was reached in 246 feet and cut at 160 feet below the croppings, about 236 feet north of the south boundary. This was the lowest point reached at the date referred to, as no efficient means were provided for the drainage of the mine. The developments made by the works thus far prosecuted, show a well-defined vein, varying in width from a mere seam to 8 or 12 feet, and sometimes more, (in one place nearly 30) filled with hard, white quartz, which carries the silver-bearing mineral, distributed through it in bunches or disseminated particles, rarely arranged in banded form, as in the Reese River veins, or in large masses, free from gangue. The pay-ground usually forms a belt near the hanging wall, not often, though sometimes, filling the whole space between the walls of the vein. The occurrence of ore also appears to be in chimneys, or distinct ore-bodies, leaving other portions of the vein small and barren. Thus, in the Combination, as shown in the section, the ore, so far as developed, occurs in one body, measuring, on the first level, about 100 feet horizontally, and, on the second, 140. The inclination of this body is to the north, dipping at about 45°. Its shorter axis, at right angles to its dip, appears, from the descriptions given, to have been about 60 feet, and its width varying from 2 to 12 feet, sometimes filling the whole space between walls. The principal silver mineral is stetefeldtite, an argentiferous ore of antimony, with which is combined sulphur, lead, copper, and iron.

The ore produced from the mine up to the middle of 1868 appears from the available records to have an average value of about $80 per ton. It is divided into two classes, of which the first assays about $90, and the second about $35 to $40. This will be given with more detail further on.

The pay-ground known to exist in this mine had been nearly worked out, from the surface to the water level, early in the summer of 1868, and the future product depended on the discovery of new bodies of ore above that level, or in openings to be made at greater depths. For this latter purpose the vertical shaft, already referred to, had been begun and provided with hoisting and pumping works, consisting of an engine, 16 inches diameter of cylinder, with three winding reels driven by friction-

gear. The shaft is sunk in three compartments, each five feet square, two for hoisting rock and one for water. This machinery, however, had not at that time been made available, having been set up in winter and rendered useless for a time by the settling of the foundations. The work was unfortunately standing idle in consequence. The bottom of the mine was looking well, however, and its further development was to be proceeded with as soon as the machinery could be properly established. The company have a large mill of 40 stamps, arranged for the treatment of both first and second-class ores, by the dry and the wet, or Washoe, process, of which some descriptive notes will be given in a following paragraph.

Belmont.—Next south of the Combination is the Belmont Company's claim, covering 850 feet. Immediately adjoining the claim of the Combination they had some excellent ground, which yielded from the croppings and near the surface a large amount of "chloride" ores, producing, it is said, over \$110,000. About 90 feet from the line a vertical shaft was sunk on the croppings 180 feet, which was standing idle when visited. The vein becomes small and pinched at no great distance from the line, and is soon lost in ground that has evidently suffered much disturbance. It is here that the fault, already referred to, occurs, the continuation of the vein appearing about 150 feet further east as the Transylvania. On this portion of the property a shaft has been sunk, about 400 feet from the south line, to a depth of 170 feet, and the vein opened by levels driven to the northward until reaching the fault, which, in the upper level, is 130 feet from the shaft, and, in the lower level, little more than 50 feet. The vein is 7 or 8 feet wide, and, near the shaft, is very regular and well defined. The ground between the shaft and the fault was found quite productive in places, and much of it was stoped out. It is said by those in charge to have yielded 2,000 tons, worth, on the average, \$50 per ton. The work was idle in the summer of 1868, partly because no greater depth could well be reached without hoisting and pumping machinery, of which there was no provision, and partly because the property was then under offer for sale in England.

Silver Bend.—Next south of the Belmont is a short claim, 150 feet in length, known as the Elmore ground, on which some work has been done;

beyond that is the Silver Bend, claiming 2,000 feet, and on which some 600 or 700 feet have been opened at a depth of about 70 feet.

The ledge on this property presents the characteristic features shown in the neighboring mines. It varies from a few inches to 8 or 10 feet in width, carrying a belt, or seam, generally near the hanging wall, in which the ore is well distributed. At the bottom of the north incline the vein is 8 feet wide, filled with quartz. The pay-seam here is two feet wide. Further south the ledge pinches to a mere seam as it passes the ravine, where a vertical shaft, 30 feet deep, located east of the croppings, connects the work with the surface, and affords ventilation. Further south the ledge widens out again, varying from 1 to 4 feet, and showing productive ground. These openings have afforded, without any stoping, between 150 and 200 tons of ore, of which 100 tons have been worked, yielding over $100 per ton, while the appearance of the remainder indicated a still higher product. Ten tons were being worked about the time that the writer was there, of which the pulp assay was $190. This mine is one of much promise. It is owned by an eastern company that has suspended active operations for a time, but will probably proceed with its development when other conditions are favorable.

South of the Silver Bend Company's claim the outcrop of the ledge turns westward, partly due to the flat dip of the vein and the slope of the surface; partly, perhaps, to a change of the course of the lode. Some other locations have been made on what is claimed as a separate ledge, though believed by many, in the absence of actual proof, to be the same ledge as that of the Silver Bend. Such are the Mountain Queen and, further south, the Quintara.

About 1,000 or perhaps 1,500 feet west of the vein above described is a succession of mines, in the earlier stages of development, which, for aught that so far appears to the contrary, are on one vein, though further developments may show them to be on several distinct veins. These are the El Dorado South, the El Dorado North, Atlanta, Arizona, and some other claims. The ledge on which they are located appears to be parallel to the Highbridge-Transylvania, but nearer the junction of the quartzites and slates with the underlying granite. The El Dorado South is the southern claim, and the most developed of all. At their works the ledge crops out plainly, showing a belt of quartz

from 2 to 6 feet thick, and sometimes thicker, dipping eastward at 30°, or 40° on the south end of the openings, and steeper on the north end. The inclosing rock at the El Dorado is a hard quartzite, mixed in places with bands or belts of slate. Further north, as at the Arizona, the inclosing rocks are more slaty in structure and general character. The general course of this ledge is north 15° to 20° west, true; and the various claims above named, regarding them as on one vein, cover several thousand feet. The El Dorado South own 2,000 feet, and have extracted from surface workings near the croppings a large amount of "chloride ores," yielding from $150 to $300 per ton, and even more. This work is said to have been the source of great profit to the owners. In depth the vein had not been extensively wrought. A shaft, or incline, had been sunk 130 feet, showing a large vein of quartz, carrying a good deal of ore; but at the time referred to, operations were confined to the surface-diggings, which were very rich in chloride of silver.

Adjoining this claim on the north is the El Dorado North, which has less development, but very good prospects. The Atlanta, the Arizona, and some others have opened this vein still further north. The Arizona was at work in June, 1868, and was producing some excellent ore from within 50 or 60 feet of the surface. The developments were not extensive, but were deemed very encouraging.

The principal mining developments of this region are centered in the locality of the veins described in the foregoing paragraphs. There are, however, in addition to these, many locations of promise, some in the immediate vicinity, others within a few miles, chiefly along the slate belt, some of which will probably become important. The Spanish district, seven miles north and west of the region just described, is very well spoken of, but was not visited by the writer.

COMBINATION AND BELMONT MILLS.—There are two mills in the vicinity of Belmont; one belonging to the Combination Company, the other to the Belmont Company. The former is a large, handsomely-built establishment, not far from the mine. It was completed early in 1868, at a cost of not less than $225,000. The methods of treatment, both wet and dry, are the same, in all essential features, as those already described elsewhere. A few notes

concerning the capacity and working of the mill are given here. It has 40 stamps, of about 800 pounds weight, dropping about 9 inches, 70 times per minute. A portion of the stamps are for dry and a part for wet-crushing. In June, 1868, 20 stamps were employed on each. For dry-crushing, screens of wire-cloth, having 40 meshes to the inch, were used. The capacity of the stamps for dry-crushing is about one ton per head, per day; for wet-crushing, one and a half to two tons.

For roasting the dry-crushed ore there are ten furnaces, generally similar in construction to those of the Manhattan or Dall's mill, already described. Each furnace works a charge of 1,000 pounds in six or seven hours. Salt of the best quality is furnished here from Silver Peak, costing about $65 per ton. There are 32 pans; 16 for the treatment of roasted ores, and 16 for raw ores, besides settlers for the separation of the amalgam from the pulp. In addition to the above the mill is furnished with retorts, melting and assaying departments, complete in all their appointments.

The machinery is driven by two engines; one for the pans, the other for the stamps. The first is a Corliss, 18 inches diameter of cylinder by 38 inches stroke; the other, an ordinary engine, 15 inches diameter, 30 inches stroke. Steam is supplied from four boilers, built in sets of two each, but connected. When the mill is employed to its full capacity all the boilers are required, burning twelve cords of wood per day. The cost of wood is from $4 to $5 per cord.

The costs of milling by the wet process are estimated at about $10; but the statements furnished are not sufficiently detailed to show the costs of either method by itself, the running expenses of the whole work being kept without close analysis.

The product of the mill, from the time of its commencing operations to the middle of June, 1868, is shown by the following statement, furnished by Mr. Bright, the financial agent of the company:

| | |
|---|---|
| In February, 1868 | $27, 697 01 |
| In March, nearly all dry-crushing | 43, 798 04 |
| In April—16 days only—all dry-crushing | 18, 750 22 |

| | |
|---|---|
| In May, 927 tons of ore—480 wet, 447 dry | $48, 212 95 |
| In June—11 days | 29, 939 03 |
| | 168, 397 25 |
| Deducting, as product of custom work | 8, 100 00 |
| Leaves, as product of Combination mine | 160, 297 25 |

In addition to which there were 2,000 tons (estimated) of second-quality rock awaiting treatment by wet process, of which the assay value was said to average $40 per ton.

The above statement does not show accurately the yield and costs of treatment of the two classes of ore, as the amalgam from both processes is usually melted together, and the costs were kept without strict classification. For the month of May we have, however, the following figures: 447 tons of first-class ore gave an assay value of $91 10, yielding $88\frac{3}{19}$ per cent., or $80 31 per ton, aggregating $35,898 33; while 480 tons of second-class ore, with an assay value of $37 70, yielded $68\frac{1}{20}$ per cent., or $25 62 per ton, amounting to $12,314 62. The average yield of the whole amount of ore worked in May was $52 per ton. The additional product of this mill during the latter half of 1868 probably did not exceed $20,000, as it was standing idle nearly all the time. The opening of the mine having been delayed by the accidents to the hoisting and pumping machinery, already referred to, the supply of ore speedily failed, and the mill, which, without this condition of affairs, was built with too great capacity, was thrown out of employment.

The Belmont mill is in the town of Belmont, a half mile or a mile from the mine. It was built in 1866. It contains 10 stamps, weighing about 600 pounds each, and 6 pans, the machinery being driven by a small steam-engine. The mill is only designed for treating ores in the wet, or Washoe process, and was successful in working the surface ores of the vein, extracting from 50 to 60 per cent. of their value. According to Mr. Wright, the agent of the company, this mill has treated about 4,000 tons of ore, yielding, on an average, $50 per ton. About one-half this product came from the northern part of

the Belmont claim; the other half from the southern part of the claim, or so-called Transylvania. During the writer's visit the mill was not crushing ore, as the mine was not producing, for reasons already stated. The pans were at work on tailings, of which there was a large accumulation on hand. These tailings assay from $30 to $50 per ton, and yield, under the simple process of the pan, about $10 per ton, the cost of treatment being $7.

The region about Belmont possesses very many natural advantages as a mining district, and, in this respect, is one of the most attractive locations in the State. The hills bear a liberal growth of nut-pine and cedar, with some mahogany, affording large supplies of fuel. Wood costs from $4 to $5 per cord, and the price can hardly increase very much for some years to come. Some large timber can also be found in the surrounding hills, supplying mining timbers, while saw-mills are established and are furnishing a rough quality of lumber. Water is abundant for present purposes, and it is said that the supply can be very greatly increased from the streams of neighboring cañons by means of ditches or aqueducts, a few miles in length, whenever the demand exceeds the amount furnished from the present sources. The town itself is agreeably located, handsomely laid out, provided with banks, assay offices, newspapers, mails, telegraphs, schools, and the other appointments of civilization. This district, like many others in this part of the State, has been very much neglected since the exciting developments were made at White Pine. Late in 1868 a large proportion of the population moved to the scene of the new discoveries, leaving the town and its neighboring mines almost entirely deserted. In 1869 there was but very little work in progress; although it is believed that the district not only possesses some good veins but also some unusual advantages, as compared with neighboring localities, in its supplies of wood, timber, water, &c.

South of Belmont, both in an easterly and westerly direction, there are several mining districts in which important developments have been made. They lie beyond the limits of the field of observation marked out for this report and could not be conveniently visited by the writer. Information concerning some of them will be found in the reports of J. Ross Browne, esq.,

and his successor, R. W. Raymond, esq., United States Commissioners of Mining Statistics.

Eureka District.—Lying farther north, and about 60 miles east of Austin, is the Eureka District, organized several years ago, partly prospected and again abandoned, until lately, when a fresh impulse was imparted to the region by the White Pine developments. This district was visited by the writer in 1868, when the developments visible were not sufficient to indicate much of the nature or extent of the deposits. The district at that time was entirely deserted, and but little definite information was available concerning the history of the work, the quantity or value of the ore obtained. The ore there, consisting chiefly of argentiferous galena, was found in limestone, occurring in bunches or pockets, of which the limits were not easy to make out. During the past year work has been resumed and valuable deposits of good ore are reported. About 50 men were said to be at work there and several small smelting furnaces were in operation. It is said that the galena is less abundant in depth, the ore changing into silver-bearing minerals of richer character, and better adapted to roasting and amalgamating processes.

Cortez District.[1]—The Cortez District is north and a little east of Austin, about 65 miles distant from that town. It is in the northern end of the Toyabe range of mountains. The district embraces ten miles square, having the summit of Mount Tenabo in the center. It is 24 miles south of the Pacific railroad. The first discoveries of mineral wealth in this locality were made in 1862 by parties from Austin, who located claims and organized the district soon after.

The principal veins of this region occur in and near a massive belt of pure white quartzite, 450 feet thick, which is inclosed by limestone, and crops out near the summit of Mount Tenabo, striking north and south, and dipping to the east at an angle of 38° from the horizon. The vein of the Mount Tenabo Company, which was one of the earliest and most important discoveries, strikes east and west, and dips to the north at an angle of 82° from the horizon. In the quartzite the vein has very well defined walls, each of which carries a clay-seam 3 or 4 inches thick. The vein is about 5 feet wide.

[1] From notes furnished by Mr. Arnold Hague.

The ores are rich in silver sulphurets, but combined with zinc, lead, and other base metals, involving the necessity of expensive metallurgical processes. The mine has been opened by a shaft, from which three successive levels have been driven.

The Mount Tenabo Company own a mill situated on Mill Creek, on the north side of the mountain. It is provided with 12 stamps, 4 roasting furnaces, 4 Wheeler and 2 Varney Pans, and 2 settlers. The reduction process is the same as that employed at Austin. The ore yields about 87 per cent. of its assay value. The mine of this company produced about 2,000 tons of ore during the three years of 1865, '66, and '67. The average yield of 850 tons during the last-named years was $67 per ton.

In 1868 work was suspended on this mine and the district almost entirely deserted. There are, however, several other important mines, some of which have been persistently worked. Among them the St. Louis is the most prominent. This vein is also in the quartzite. It produces some very rich ore, which was formerly sent to Austin for reduction, but is now worked in the mill just referred to, which has been leased or purchased from the Mount Tenabo Company.

The Garrison mine, opened in 1868, is also an enterprise of considerable promise. This vein is in the limestone, below the quartzite belt. A quantity of its ore, about 50 tons, yielded $250 per ton, when worked at the Manhattan mill in Austin.

Conflicting interests, mismanagement in some cases, want of capital in others, and the great costs of working in former years, have greatly retarded the development of this district. It is now growing in importance. It is quite easily accessible from the railroad, and is well supplied with wood and water.

According to the quarterly returns of the county assessor the St. Louis mine produced, during the year 1868, 88 tons of ore that yielded an average of $600, currency, per ton.

The assessor's return from the district, for the quarter ending December 31, 1869, is as follows:

| Name. | Amount. | Yielding per ton in coin— |
|---|---|---|
| | *Tons. Lbs.* | |
| St. Louis Company | 25 863 | $67 56 |
| Mt. Tenabo | 13 1546 | 57 80 |
| Berlin | 9 1593 | 153 78 |
| Arctic | 76 27 | 55 66 |

MINERAL HILL DISTRICT.[1]—This district is situated on the west side of the Piñon Mountains, near the southern end of Pine Valley. The town is 37 miles from Palisade, the nearest station on the Pacific railroad, 435 miles from Sacramento. It is 42 miles from Carlin, and 91 miles from Austin.

The mining operations of the district are centered in an isolated hill, standing out from the main range, at the base of which the town is situated. The summit of this hill is nearly 500 feet above the town.

The district was discovered and the first locations were made in June, 1869. At the date of these observations, three months later, all the mining locations then made were upon the west side of the hill, scattered over the slope from base to summit. The whole side of the hill is a mass of quartzite and limestone, very much broken up. All the "ledges" dip to the eastward into the hill, but at varying angles. They have a general strike of north and south. The principal claims are the Live Yankee, Great Republic, and Austin.

At the time referred to, September, 1869, about 50 tons of ore had been reduced at the Manhattan mill, in Austin. It is said to have yielded $400 per ton. There remained on hand a considerable amount of ore, the value of which was estimated at $200 per ton. At that time there had been no very extensive work on any of the claims; the ore obtained had been taken out from small chambers, or pockets, near the surface. There was no mill in the district, but negotiatious were in progress for the erection of one in the ensuing spring.

[1] From notes furnished by Mr. Arnold Hague.

Water is easily obtained in the neighboring cañon of the main range. It is also said that a sufficient supply for milling purposes can be had by sinking wells. Wood is plenty in the neighborhood and communication with the railway is easy.

The reports from this district, of a later date than the above, are very favorable; but the writer has no definite or reliable information concerning the new developments.

## SECTION IV.

### GEOLOGY OF THE WHITE PINE DISTRICT.

BY ARNOLD HAGUE.

The White Pine mining district is in the eastern portion and not far from midway between the northern and southern boundaries of the State. According to Lieutenant Wheeler's observations, made in the summer of 1869, Treasure Peak, about which the principal mining operations are centered, is in latitude 39° 14′ and longitude 115° 27′ west from Greenwich.

Hamilton, the principal business town in the district, is 120 miles distant from Austin, by way of the traveled roads, and a few miles south of due east from that point. It is 110 miles, in nearly a southerly direction, from Elko, the nearest station on the Central Pacific railroad, 468 miles from Sacramento. Communication is sustained between Elko and White Pine by means of several stage and freighting lines, on roads that are tolerably good during the greater part of the year.

The White Pine Mountains are a prolongation to the south of the Humboldt chain; the main range of the Great Basin, in point of breadth and elevation, lying between the Wahsatch, of Utah, and the Sierra Nevada, of California. From the Humboldt River the range extends south for nearly one hundred miles in an almost unbroken line of high rugged peaks, rising 5,000 or 6,000 feet above the adjacent plain; then falling away gradually, it only appears as a few low, irregular, broken ridges, formed by gentle, undulating folds in the strata of the overlying limestone. These ridges rise with an easy slope to an elevation of only a few hundred feet above the valleys, and may be readily crossed at almost any point. About ten miles to the north of Treasure Hill the mountains rise gently until they culminate in Pogonip Mountain; then they commence to descend more abruptly, and six miles to the south again become quite low. This isolated, mountainous group, between the two low depressions in the range, is known as the White Pine Mountains.

The White Pine mining district includes an area of twelve miles square,

with the celebrated Treasure Hill as a central point geographically, as it is the central point of the mining industry. The mountains, as well as the district, take their name from the very considerable growth of pine which covers both the east and west slope of Pogonip Mountain. The timber of the district is almost exclusively confined to the western ridge, for, with the exception of a few localities upon Babylon Hill, timber is either entirely lacking or is of a very dwarfed character. There are among the trees several species of pine and juniper. Although well favored as regards wood in comparison with the greater part of Central Nevada, the timber is of small growth, rarely reaching a height exceeding 30 feet. The White Pine Mountains, from the eastern foot-hills to the valley at the base of the western slope, have an average width of 12 miles. Within this limit they are divided into three distinct north and south ridges, measuring in width from the two outer crests about five and one-half miles.

By reference to the map,[1] Atlas-Plate 14, these mountain elevations may be easily recognized. To the west we have Pogonip Ridge, with the highest point designated as Pogonip Mountain. The middle ridge, a more complicated structure, includes Treasure Hill, which comprises Treasure and Telegraph Peaks; the Base Metal Range, which comprises Babylon Hill and Mount Argyle; and the Blue Ridge.

Mokomoke, the third elevation, lies east of the middle ridge. The name Mokomoke is frequently applied to the prominent hill in the ridge that rises above Hamilton. These mountain elevations are connected by low, narrow saddles, to the south of which they are separated by two deep, narrow valleys, known as Applegarth and Silver Cañons, which unite about five miles to the south, forming one large cañon, trending off to the south and west of Pogonip. North of these saddles, Pogonip and the Base Metal Range are separated by Pogonip Cañon; and the eastern and middle ridges, by a broad basin, upon which the town of Hamilton is built. The altitude above the level of the sea of a few of the most prominent elevations and important points is as follows: Pogonip Mountain, 10,792 feet; Babylon Hill, 9,247

[1] This map includes the area covered by Mr. Hall's grade-curve survey of Treasure Hill; and much of that gentleman's work has been used in the preparation of Atlas-Plate 14.

feet; Telegraph Peak, 9,228 feet; Mokomoke Mountain, 9,239 feet; Treasure City, 8,980 feet; Hamilton, 8,003 feet; Shermantown, 7,257 feet; Manhattan Mill, 7,547 feet.

Pogonip Ridge towers grandly above the surrounding country. It rises with steep, precipitous slopes, 1,500 feet above Babylon Hill; while to the west it falls off in long, rugged spurs, several thousand feet to the valley below. Pogonip Mountain commands, upon a bright, clear day, one of the finest and most extended views that can be obtained in this part of the State. The structure of the ridge is quite simple, trending nearly north and south. The geological formation of the eastern slope is composed of a grayish-blue limestone, striking with the trend of the ridge and dipping with an angle of 22° to 25° to the east. But few fossils were found, and in a much less perfect state of preservation than those of allied forms from the strata of Treasure Hill.

The middle ridge is the most complicated of the three in its geological features, and by far the most important, from its great mineral wealth. The two main features of the structure are, first, a well-marked anticlinal fold, whose axis, although somewhat flexed, has, in general, a north and south direction. Secondly, a transverse fracture and displacement of the rock, which extends across the ridge at the southern end of Treasure Hill.

The axis of the anticlinal fold follows and forms the cañon or ravine separating the Base Metal Range from the Blue Ridge, then bending around the north end of Telegraph Peak, continues along the east slope of Treasure Hill, 500 feet below the summit, through the mining settlement of Pocotillo and the hill upon which the Argyle mine is located.

This anticlinal fold occurs in limestones, whose western slope constitutes the entire formation of the west side of Treasure Hill and the Base Metal Range, with the exception of some overlying shale and siliceous limestone, which cap the top of Telegraph Peak and the northern slope of Babylon Hill. These westerly dipping beds form, with Pogonip Ridge, a synclinal fold.

Treasure Hill, from Telegraph Peak to the Eberhardt mine, is about one mile and a quarter in length; across Treasure Peak the width is one mile and three-quarters. To the north it falls off, in a steep, rough slope, to

the town of Hamilton, 975 feet below; on the east a precipitous wall, 400 feet in height, descends to Pocotillo. The limestone strata, at the summit of the hill, dip westerly, at an angle of 9° to 10°, and strike nearly north and south.

About 200 feet below the crest of the ridge, along the west slope, are situated Bromide, Chloride, and Pogonip "flats." In structure they are simply floors of distinctly bedded limestone, which, dipping at a gentle angle, from 7° to 10°, to the west, have received the above designation. The flats are separated from each other by well-marked, natural boundaries—walls of limestone, from 12 to 20 feet in height. The three flats, taken together, are a little more than a quarter of a mile in length, by 550 feet in width; at the lower end they terminate abruptly in a cliff, from 150 to 200 feet in height; below which the strata are much disturbed, and of a very irregular dip and strike down to the bottom of Silver Cañon.

At the foot of the escarpment which forms the southern limit of Pogonip, occurs the fracture and displacement of strata already mentioned. This fracture extends entirely across the ridge, with a course approximately at a right-angle to the axis of the main anticlinal fold. It contains the Eberhardt deposit, and caused the formation of the two small east and west cañons, heading near the Eberhardt mine, the one trending toward Applegarth and the other toward Silver Cañon.

South of this fracture the formation becomes very irregular, having been broken up by local faults, displacements, and sharp folds. Southeast of the Eberhardt mine, upon the hill on which the Argyle mine is located, the strata of the east side dip toward Applegarth Cañon at an angle of 36°; on the opposite side they dip westerly at an angle of 58°. These westerly dipping strata form the east wall of Mahogany Cañon, dipping toward the cañon. The strata upon the opposite side of the cañon are found dipping to the east.

Upon Babylon Hill and the Base Metal Range we find the same limestone formation, less disturbed, and more uniform in dip and strike.

Babylon Hill rises above the town of Swansea, in bold, precipitous cliffs. The summit of the hill is broad, sloping gently toward the south and west, until it overhangs Poyonix Cañon, where it presents steep, rugged walls. At the northern end of the Base Metal Range the strata strike at an angle of 20°

to 25° west of north, and dip westerly at an angle of 26° to 28°. Upon Babylon Hill they maintain the same dip, but strike from 35° to 40° west of north. Nowhere, within the limits of the district, do the beds underlying this formation of limestone appear at the surface. We have, therefore, no means of knowing its thickness. There is, however, at least 1,500 feet of strata exposed. The uppermost beds of limestone are highly fossiliferous. The fossils obtained place the age of the formation without doubt in the Devonian period. The limestone is of a bluish-gray color, hard and compact. Near the ore-bodies, where subjected to the same chemical action which produced the metalliferous deposits, it is highly impregnated with foreign matter, particularly with silica; but where removed from such action, it is remarkably pure.

A limestone specimen, taken from the east bluff of Treasure Hill, has been analyzed by Mr. O. D. Allen, of the Sheffield Laboratory, Yale College, with the following result:

| | |
|---|---|
| Lime | 55. 38 |
| Magnesia | . 25 |
| Carbonic acid | 43. 70 |
| Insoluble residue | . 70 |
| | 100. 03 |

The insoluble residue contained a little iron.

Immediately overlying the Devonian limestone occurs a formation of thinly laminated calcareous shale. The color of the shale is dark-gray; many of the beds, however, are interstratified with thin, reddish-gray bands, alternating with those of a dark-gray color. This shale has been eroded off from the greater part of Treasure Hill. It is found, however, on the depression between Treasure and Telegraph Peaks; underlies the summit of the latter point, and may be traced for quite a distance along the western slope of the hill, dipping conformably with the limestone. Its thickness may be best determined upon the east side of Treasure Hill, immediately above Applegarth Cañon, where it is about 125 feet. The calcareous shales, as far as yet known are entirely non-fossiliferous.

The formation overlying this calcareous shale is a granular, siliceous limestone; much of it is completely metamorphosed into beds of hard, compact chert, frequently interstratified in their layers with the more calcareous beds. The purer calcareous beds often contain masses and nodules of chert imbedded within them. The top of Telegraph Peak is of the siliceous limestone, the immediate summit being composed of a dull, brownish-red chert. The thickness of the siliceous limestone formation is about 100 feet.

The calcareous shale and siliceous limestone formations occur on the summit of the Base Metal Range, the former covering the long gentle slope to the northwest. (See Atlas-Plate 14.) Upon the east side of the anticlinal fold, overlying the Devonian limestone, are found the shale and limestone, as observed upon the west side. They appear along the east base of the Blue Ridge. From there to the head of Applegarth Cañon a few outcrops of the siliceous limestone are found, but the greater part has been eroded off. Following the line of the axis of the fold, both formations are found, occurring regularly along the east side of Treasure Hill, where the entire formation appears to be compressed together and thrown up at a sharp angle. The dip of the strata along the east side of the hill is from 32° to 37° to the east. The formation next overlying the siliceous limestone is a black argillaceous shale. The lower beds are quite hard and compact, but rapidly pass into layers more laminated in structure, which, near the top, become quite arenaceous. Many of the beds carry narrow seams of bituminous matter. These argillaceous shales have a thickness of about 600 feet. The depression, or basin, in which Hamilton is situated, as well as the bottom of the Applegarth Canon, is in this latter formation. At White Pine streams of water and natural springs are quite rare; nearly all of them occurring in this shale formation. At Hamilton a number of wells have been sunk, furnishing good water; the same may be said of Applegarth Cañon, where there are several natural springs.

Mokomoke Ridge has a general north and south trend. The geological structure is very simple. The rocks are perfectly conformable, striking with the trend of the ridge, and dipping at an angle of 22° to the east. The above description does not, however, apply to the ridge, above the saddle, connecting with Treasure Hill, along the southwest side of Mokomoke Moun-

tain. Here the sandstone and limestone formations have been considerably distorted. At one place both formations are seen dipping westerly. On the summit of Mokomoke Mountain the limestone is found lying almost horizontally. Immediately above the argillaceous shale occurs a belt of fine-grained, reddish-yellow sandstone, whose thickness is estimated at about 300 feet.

Next in order above the sandstone occurs a body of light-yellow, granular limestone. The formation is highly fossiliferous and rich in remains of well-marked carboniferous types. From the sandstone to the summit of the ridge we have several hundred feet of the limestone exposed, but, as nowhere within the district do the overlying beds appear, the entire thickness cannot be given.

At Swansea, in Silver Cañon, the argillaceous shale, sandstone, and carboniferous limestone are found. The beds are very much disturbed, and occupy only a limited area.

The paleontological evidence of the position of the White Pine rocks is such as to determine conclusively the age of both the upper and lower limestone formations. The clue to the age of the other beds, judging from the fossils alone, is not quite as satisfactory. Their position, however, between well-defined Devonian and Carboniferous rocks is sufficient proof that they belong either to the one or the other of these periods. In the Devonian limestone, as far as known to the writer, no fossils have as yet been obtained from the lower beds. The overlying beds, however, are in many places highly fossiliferous, and for several hundred feet below the uppermost stratum, fossils of well-marked Devonian types are abundant.

The writer is indebted to Mr. J. E. Clayton, a mining engineer residing at Hamilton, for information in regard to the localities of many interesting fossil-bearing beds, and also for many valuable specimens from his private collection.

The most interesting fossiliferous beds may be found upon the summit of Treasure Hill, along the east bluff, in the neighborhood of the Argyle mine; on the east side of the Blue Ridge, above Hamilton, and near the summit of Babylon Hill. Upon Treasure Hill may be found *Diphyphyllum*, *Chonophyllum*, *Favosites*, *Alveolites*, *Matrocheilus*, *Orthoceras*, *Ace~~mularia~~* rvularia, *Atrypa reticularis*, *Spirifer engelmanni*, *Spirifer utahensis*. In addition to many of the above,

on Babylon Hill may be found *Syringopora*, *Retepora*, and *Smithia hennahii*. On Blue Ridge *Pleurotomaria* and a small *Productus;* the latter, however, are extremely rare.

The following note, from Professor F. B. Meek, to whom the collection was referred, will be sufficient for the purposes of this chapter:

"The genus *Smithia* is generally regarded as a Devonian type, while the specimens of that genus in the collection seem to be very closely allied to, if not actually identical specifically with, a well-known European Devonian species. The genus *Acemularia* is also mainly a Devonian type, only some three or four of the thirteen or fourteen species which occur in the Silurian, being found in the rocks of any other age; while the single species of this group, contained in the collection, is apparently identical with a well-known European Devonian species. Among the molluscan remains from this rock we have the well-known *Atrypa reticularis*, which, however, occurs both in the upper Silurian and Devonian, though it is not known to be represented by any of the forms usually referred to it in any part of the Carboniferous series. But here we have it directly associated with a small *Productus*. This last-mentioned genus, although most abundant in the Carboniferous, likewise occurs in the Devonian, but has not yet been found in the Silurian. So that the association of these two types, in the same beds, again points to the Devonian. The associated *Spirifers* are most nearly allied to Devonian species; while scarcely any of the other fossils from this rock can be properly said to point to the Silurian or the Carboniferous."

The calcareous shale, as already remarked, is entirely non-fossiliferous. The siliceous limestone formation contains large numbers of *Crinoid* stems. Large masses of chert occur, completely filled with fragmentary remains of *Crinoids*, in silica, while, in the pure limestone, occur the same remains, but of nearly pure white calcite.

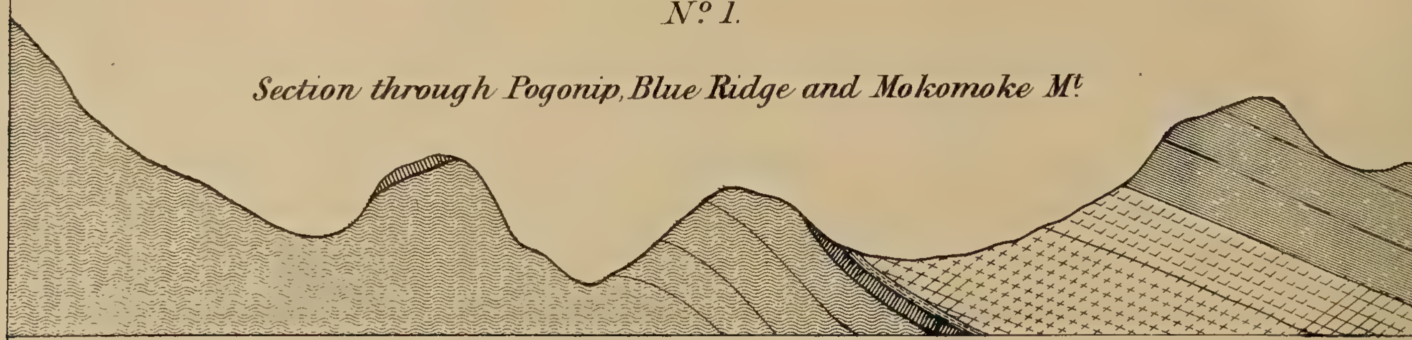
In addition to the *Crinoid* stems, *Productus* and *Spirifer* are found; of the former a small single valve, and of the latter, molds of a dorsal value in chert. They are not sufficiently well preserved, however, to determine the species definitely.

The evidences of the age of the argillaceous shales seem to indicate that they belong to the Carboniferous period, although they are not such as to warrant the positive assertion.

# White Pine Sections.

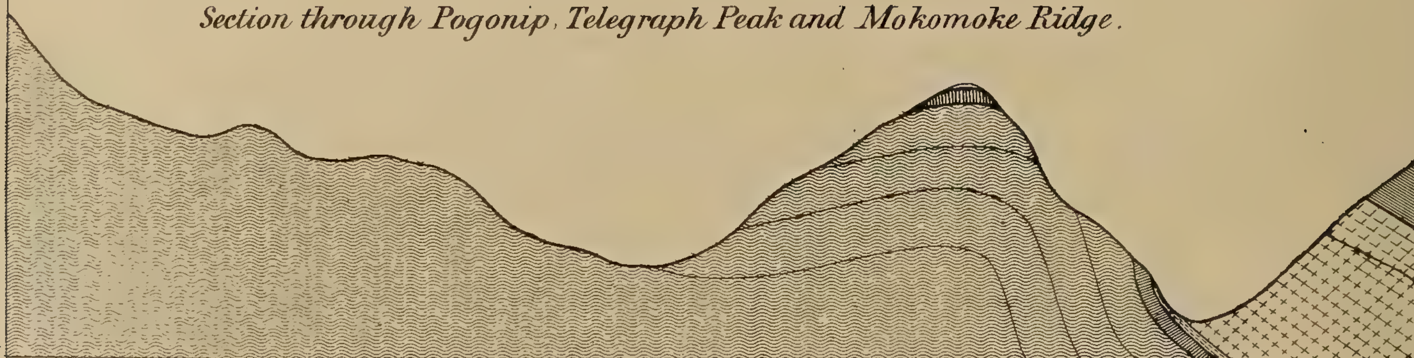
## No. 1.

*Section through Pogonip, Blue Ridge and Mokomoke Mt.*



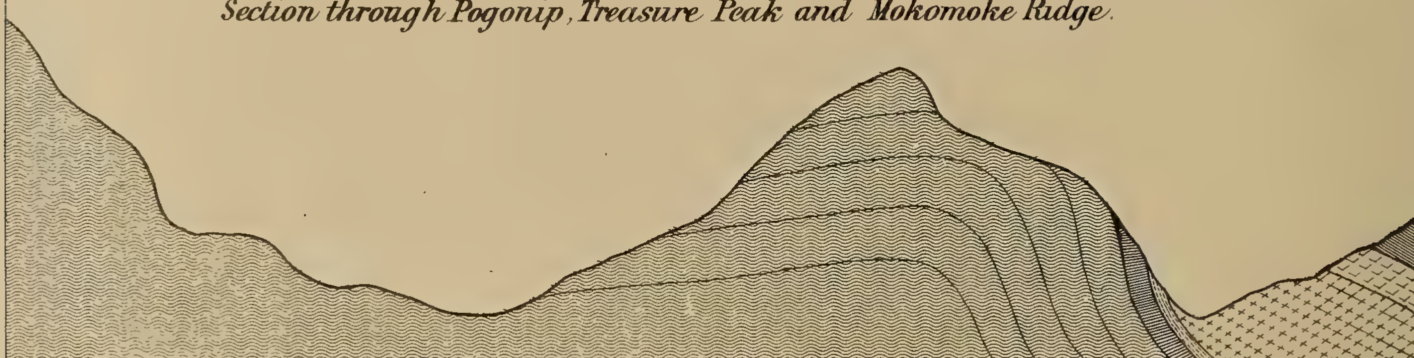
## No. 2.

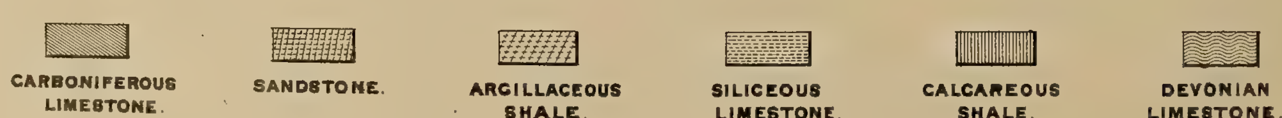
*Section through Pogonip, Telegraph Peak and Mokomoke Ridge.*



## No. 3.

*Section through Pogonip, Treasure Peak and Mokomoke Ridge.*






HORIZONTAL SCALE: *3520 feet to 1 inch.* VERTICAL SCALE: *1500 feet to 1 inch.*

Many of the beds are quite rich in fossils, but the specimens obtained are either not sufficiently well preserved for determination, or the association of species is such that the exact age of the formation may be doubtful. The following forms occur: *Athyris, Pleurotomaria, Ariculopecten, Naiadites, Lecorhynchus.* Professor Meek, speaking of the collection of specimens from these beds, says:

"The *Lecorhynchus*, if it really belongs to that genus, would, judging from the known position in New York of the species, rather point to the Devonian. The *Ariculopecten* and *Naiadites* however, would, on the other hand, furnish very strong evidence that these dark beds belong to the Carboniferous."

The sandstone beds are very poor in fossil remains. In the lower strata, next the shale, are found a few impressions of leaves of the genus *Lepidodendron*, and with them, although rare, the genus *Cordaites;* these constitute, with the exception of some indeterminable fragments of *Crinoid* stems, all the remains yet found.

The Carboniferous limestone is highly fossiliferous, and rich in remains of well-marked types, nearly all the species being identical with well known European or American Carboniferous forms. The following are among the most characteristic species: *Productus longispinus; P. semireticulatus; P. scabriculus; Spirifer cameratus.*

Upon the map of the White Pine District, on Atlas-Plate 14, the non-fossiliferous, calcareous shale and the siliceous limestone are colored brown, as belonging to the Devonian. The evidence in regard to the age of the argillaceous shale and sandstone points so strongly to the Carboniferous that they are both colored blue, as belonging to that period.

The accompanying sections, Plate XXVIII, show the relation of Treasure Hill to the surrounding country, and, although drawn with a vertical scale greatly exaggerated over the horizontal, serve to point out the relation and position of the different formations. They are cut on an east and west line. No. 1 crosses the summit of the Blue Ridge; No. 2 crosses Telegraph Peak; No. 3 crosses the southern end of Treasure Peak and Pogonip Flat.

All observations of the mining explorations and developments of the ore-bodies show that, in their geological position, the metalliferous deposits are

exclusively confined to the Devonian limestone. The highest stratigraphical position of any mineral deposit yet found occurs along the line of contact between the limestone and the overlying calcareous shale.

The mode of occurrence of the silver deposits upon Treasure Hill is exceedingly varied; these may, however, all be classed under four heads:

First. In fissures, dipping at a highly-inclined angle, and striking approximately east and west; that is, across the strike of the limestone of the hill.

Second. In contact deposits, between the limestone and calcareous shale.

Third. In beds or chambers in the limestone, parallel to the line stratification of the rock.

Fourth. In irregular, vertical, and oblique seams, or joints, across the bedding of the rock, and having most frequently a north and south course.

The Eberhardt mine affords the finest and most marked example of a fissure, if, indeed, it is not the only one occurring upon Treasure Hill which extends to any great depth below the surface. The width of the claim between the walls is 200 feet. The strike is nearly east and west. The north wall presents a smooth, clean surface, dipping 78° to 80° to the south.

The material inclosed between the walls is by no means all ore; a large part of it is composed of masses of barren limestone, surrounding which is the quartz and ore-bearing material. The gangue of the ore is made up of pieces of broken limestone of irregular shape and size; some of it presents the appearance of hard, compact grit; much of it is very fine and completely impregnated with silica, the entire mass being held together by fine granular quartz, which fills up the intervening space. The silver, as cerargyrite, or chloride of silver, occurs finely disseminated through the gangue. In the richer bodies of ore the chloride is found coating and incrusting in their layers the more solid pieces of quartz; sometime it occurs filling up or lining the cavities and druses.

The contact deposits are found at the north end of Treasure Hill, wherever the calcareous shales are found in place. All along the line of contact of the two formations may be traced the characteristic minerals that accompany the silver deposits; quartz, calcite, ferruginous matter, all more or less impregnated with chloride of silver and traces of the base metals.

This material rarely penetrates more than two or three feet into the overlying formation. Within this distance the shale is split up and interstratified with quartz and calcite seams.

Explorations made in this material have developed several chambers of rich ore lying in the limestone below, and a number of mines have been located along the contact of the two formations. The Hidden Treasure is the best example of this class of deposits and one that has furnished a great deal of rich ore. The deposits of ore occurring in beds and chambers upon Bromide, Chloride, and Pogonip Flats are exceedingly irregular in size and shape; sometimes they are found filling depressions in the rock, at others lying between well-marked beds of stratified limestone; again they are deposited upon beds or floors and penetrate the inclosing limestone, either above or below.

Intimately connected with the beds are the vertical and oblique channels of ore; these vary in width from a few inches to several feet. They are generally connected with the beds or chambers, and branch out from them, frequently extending from one bed of limestone through to the next one below, many of them connecting beds of rich ore. Frequently these channels extend from the principal deposits for a considerable distance, and then terminate abruptly; occasionally they are quite wide, and maintain a continuous course for a long distance.

Whatever the occurrence of the different bodies of ore on Treasure Hill may be, the characteristic mineral composition of the material is the same under all conditions, and similar to that of the Eberhardt mine and contact deposits, already described, varying only in the richness of the ore, in chloride of silver, and the amount of the accompanying base metals.

Observations upon the position and occurrence of the ore-bearing bodies seem to indicate that they must all have had a similar origin, and have been filled from the same common source of supply. Judging from the developments thus far carried on it seems highly probable that the Eberhardt fissure has served as one of the principal sources for the supply of ore scattered over the hill. The ore in the main channel finding cracks and seams in the limestone may have extended laterally until, meeting the vertical and oblique cracks, it has been forced upward, penetrating wherever the rock afforded any

openings. Again, the ore may entirely, or in part, have ascended the main channel until, coming in contact with the overlying and impenetrable shale, it may then have been forced out laterally, forming a stratum of metal-bearing matter between the limestone and shale, and, where meeting with openings and depressions in the lower rock, penetrating through them, filling them from above.

At a later period the overlying shale and ore stratum has been eroded, leaving the openings and chambers, filled with ore, exposed, without any visible connection with each other at the surface.

This latter hypothesis appears all the more probable when we are able to see the shale, with the quartz and ore-bearing material below, still in place upon the north end of Treasure Hill. It may be remarked that what has been said of the geological position of the ore-bodies upon Treasure Hill applies to the deposits on the Base Metal Range. In general these latter bodies are far less rich in silver and carry more lead and copper. Those which have been most developed are rich, argentiferous lead ores, and occur most frequently at a lower stratigraphical position than the purer and richer chloride ores of Treasure Hill.

The following analysis of rich White Pine ore, by Mr. O. D. Allen, serves to show its chemical character. The specimens from which the analysis was made were taken from the Aurora South claim on the day of the writer's visit; they were carefully selected, and contain both the gray and green chloride of silver:

| | |
|---|---|
| Gangue, nearly pure quartz | 84.005 |
| Sesquioxide of iron | .390 |
| Alumina | .068 |
| Lime | 1.008 |
| Lead | 2.186 |
| Copper | .962 |
| Silver | 5.685 |
| Arsenic | .548 |
| Chlorine | 1.641 |
| | 96.493 |

Besides the above determined ingredients, the ore contained manganese, magnesia, sulphur, and carbonic acid. Minute traces of bromine were also detected, but no iodine. The amount of chlorine present is sufficient to combine with 4.998 per cent. of silver, leaving .678 of one per cent. of silver to be combined with arsenic and sulphur. The carbonic acid was undoubtedly combined with the lime, magnesia, lead, and copper.

The minerals of the White Pine district are very few. The following list comprises, as far as known, all those that have as yet been identified: Quartz, calcite, (white and black,) gypsum, fluorite, barite, black oxide of manganese, rhodonite, rhodochroisite, cerargyrite, galena, cerussite, azurite.

Quartz and pure white calcite are found associated together in all the argentiferous ore-bodies. The black calcite occurs in many of the mines, and is regarded by the miners as a good indication of ore. Gypsum, apparently rare, is found in small quantities in the Pogonip and Othello and Truckee mines. Fluorite, rare, of a deep purple color; barite, associated with fluorite. Black oxide of manganese occurs in many of the mines; abundant in the Pogonip and Othello and Pocotillo. Rhodonite (silicate of manganese), of flesh-red color, occurs associated with rhodochroisite (carbonate of manganese) in the Pocotillo mine. Cerargyrite (chloride of silver), massive, also reported to have been found in the Eberhardt mine in small crystals, color grayish-green, yellowish-green. The "gray" and "green chlorides" of the miners have apparently the same composition, the color depending on the manner in which the other mineral substances are intermixed with them and on the more or less disintegrated condition of the quartz. Azurite (blue carbonate of copper) forms a thin coating upon the quartz and limestone in many localities. It occurs only sparingly in most of the mines of Treasure Hill. At the north end of the hill it is somewhat more abundant, particularly at the Virginia mine; on the Base Metal Range it is of common occurrence. Galena occurs in several localities on the Base Metal Range, associated with cerussite (carbonate of lead). The developments upon the Base Metal Range have extended to such a short distance below the surface that they have, as yet, afforded very little opportunity to study the mineralogical character of the ore.

## SECTION V.

### MINING AND MILLING IN WHITE PINE DISTRICT.

The first discovery of silver-bearing lodes or deposits in the region now known as White Pine District was made in the autumn of 1865, on the west side of Pogonip, or White Pine, Mountain, near where the Monte Christo mill now stands, ten or twelve miles distant from the present center of mining operations. The district was organized in the month of October of the same year, deriving its name from the mountain on whose sides an abundance of fine timber is found. Its limits were so defined as to include an area of twelve miles square; and a code of laws was devised and adopted by the miners, in accordance with the general usage in such cases, to regulate the location of claims.

The earlier discoveries of silver, though considered sufficiently important by the owners to induce them to proceed with the development of the ledges and to erect a mill for working the ores, were not such as to attract great attention from other parties; and it was not till about two years later that the first claim was located on Treasure Hill, to which point the observation of white men was then directed by an Indian. This claim was made on the ground since developed by the Hidden Treasure and Rathbun companies, and, about two months later, was recorded, on the 14th of November, 1867. The Eberhardt mine, still more remarkable for its great wealth, was located in January, 1868, and during the summer of that year the great developments followed which attracted thousands of people to the scene of the new discoveries, and made the name of the district famous far and wide.

Treasure Hill, within the limits of which the principal silver deposits, thus far developed in the district, have been found, is an isolated ridge, about three or four miles long, in a north and south direction, by one and a half or two miles wide. Its eastern slope descends steeply, precipitously in some places, to Applegarth Cañon, which divides Treasure Hill from the next eastern range of mountains. On the western side the surface is likewise steep, descending to the bed of the cañon below, and then rising again, forms a low ridge, known as the Base Metal Range. This ridge is nearly parallel in trend

to Treasure Hill, and lies between the latter and the main White Pine Mountain.

The north and south slopes of Treasure Hill are gentler than the eastern and western. Near the foot of the north slope is the town of Hamilton, the county seat and the business center of the district. On the southern and southwestern slopes are the towns of Eberhardt and Sherman, the former situated at the junction of Applegarth and Mazeppa Cañons, the latter in Silver Cañon. In the neighborhood of Sherman are several mills, enjoying the advantages of cheap fuel and water, the latter sufficient for milling purposes, though not for motive power. A little north of Sherman, in the same cañon, is situated the small town of Swansea, in the neighborhood of which are several smelting furnaces for the treatment of ores produced in the Base Range.

Treasure City, next in business importance and population to Hamilton, is near the summit of the hill. It is nearly 9,000 feet above the sea, about 900 or 1,000 feet above Hamilton, and at an average height of about 1,200 feet above the surrounding valleys. It is in the center of mining operations. The town is laid out upon a comparatively even or gently sloping surface, which forms a narrow bench or plateau on the western side of the hill, between 200 and 300 feet below the peak. The crest of the hill, measured along this surface, from north to south, is about a half mile in length, including the areas at the southwestern extremity, known as the Bromide, Chloride, and Pogonip Flats. These flats are in, or just below, the town; they are covered by hundreds of mining claims, and crowded with pits or shallow shafts, from which have been taken large quantities of rich silver ore. Along the crest of the hill, within the limits of the half mile, but just above the town, are situated some of the most important mines of the district, such as the Aurora South, Aurora Consolidated, and others, less famous but very productive, at the south end of the ridge, and the Hidden Treasure, Rathbun, and others further north. The celebrated Eberhardt is on the southern slope of the hill, a quarter of a mile south of the Aurora, and about 400 feet lower. Beyond this, the south end of the hill is covered with mining claims; among the most important are those of Mahogany Cañon on the southeastern, and the California on the southwestern slope. The north end of Treasure Hill has not proved to be so rich as the southern. It has been extensively prospected, and some

valuable locations have been made. Among these the Virginia is the most developed and productive. Its ores, however, are said to differ essentially from those of the mines above named, the silver being combined more intimately with metals of inferior value.

Eberhardt.—The Eberhardt claim, which now includes the Keystone and others that were originally made in the same vicinity, extends in an east and west direction across the south slope of Treasure Hill, some 700 feet below the peak. The total length of the claim, acquired by location and by purchase, covers 1,800 feet. It is described as a "ledge," or true fissure vein, and held under laws which apply to that form of deposits; but whether it is such, or what its true relations are to a fissure vein, is a matter concerning which intelligent men hold conflicting opinions. It may not be a fissure vein, in the generally accepted sense in which that term is used, although it possesses some analogous features that are more notable in this than in many of the other productive deposits of the district. It is situated in the line of a fissure or fault that has broken and displaced the limestone strata, which here compose the country-rock. The direction of this break is east and west, traversing the south end of the hill. The line of fracture is perfectly well marked, showing, as far as exposed by the Eberhardt workings, along the surface or in depth, an east and west course and a dip to the south of about 85°. This is regarded as the north wall of the Eberhardt ledge. It has been traced along the surface for a distance of several hundred feet; a shaft has been sunk upon it 192 feet, and at the depth of 85 feet a drift has been run 240 feet, in all of which work the plane of fracture is shown to be regular and well defined.

South of this "wall," 184 feet distant, when measured on the surface at the Eberhardt deposit, is a similar line of fracture, though less well defined, having about the same course, and dipping to the north at an angle between 85° and 90°. This is regarded as the south wall. Included between them is the Eberhardt deposit, which, when visited by the writer in September, 1869, appeared to extend across the "fissure" from side to side, and longitudinally, between 100 and 200 feet. The depth from which ore was being, or had been, extracted, in considerable quantities, did not exceed 50 feet. The material composing the deposit consists chiefly of brecciated or shattered limestone, the small fragments of which are held together by quartz and crys-

tallized calcspar. In some places the limestone has become highly silicified. The ore, consisting chiefly of chloride of silver, is associated with the quartz and spar. In some parts of the deposit large masses of limestone, spar, and quartz, taken together, seem to be richly impregnated with the precious mineral, so that the whole may be crushed and amalgamated without assortment. In other places some assortment is necessary to select the pay-rock from the poor; and in the cut exposed, at the time referred to, there were also large portions of limestone, apparently quite barren. The general appearance of the ordinary, or low-grade, ore does not always show any indication of its value to an inexperienced eye, and even those who are most familiar with the rock are sometimes deceived.

The deposit is probably the most remarkable occurrence of hornsilver on record. In the early days of its development, channels or courses of ore were passed through that were almost solid hornsilver. A lump of ore was shown to the writer weighing several hundred pounds, apparently composed almost entirely of this material. One lot of ore of 22 tons, taken out during the first summer's work, had an average assay value of over $5,000 per ton. It was at first intended to send this ore to Europe for metallurgical treatment, but this being found inconvenient, it was milled at home, netting $96,459 46.

The character of the ground in depth is not so well ascertained. There has been a shaft sunk on the north wall, as already described, to the depth of 192 feet. This was done more for the purpose of establishing some points in litigation than for ascertaining the value of the rock. Short drifts are said to have been run northward, through the wall, in solid limestone; southward, or in the "ledge," the drift passed through brecciated limestone with quartz and spar, from which specimens were taken that had a high assay value; but the mass of ground is represented as being limestone. The rock is apparently very poor as compared with that above, but it is believed to be rich enough to pay. This shaft was inaccessible at the time of the writer's visit, and, therefore, was not seen in depth. On the south wall there has also been a shaft sunk, though not so deep as the one just referred to. From it three short drifts into the ledge afforded about the same results as those from the north shaft, showing large masses of poor limestone, but carrying with it some quartz and spar and ore-bearing ground. What the mine may be capable of yielding in depth

remains to be developed. The extraction of ore was, at the time referred to, confined to the deposits on the surface, where 25 men were at work quarrying out the rock, assorting and sacking the ore, getting out about 25 tons per day for milling. The yield of this is stated at between $100 and $200 per ton. There appeared to be a large quantity of rock on hand, described as low-grade, estimated to yield $50 or $60 per ton.

There are two mills at Sherman, belonging to this company, in which their ores are worked. Some descriptive notes of these mills and methods employed in working the ores will be found further on. The following is a partial statement of the yield of this mine up to September, 1869. It was furnished to the writer by Mr. E. H. M. Bailey, accountant for the company. It is said not to include all that has been produced from the company's claim, as the early records were imperfect. The total yield up to the same date is estimated at $1,500,000, coin.

According to Mr. Bailey there have been worked

| | |
|---|---|
| 22 tons of selected ore, producing, net | $96,459 46 |
| 2300 tons, producing $300 per ton | 690,000 00 |
| 600 tons, producing $200 per ton | 120,000 00 |
| 744 tons, producing $148 per ton | 110,112 00 |
| 1200 tons, producing $102 per ton | 122,400 00 |
| | 1,138,971 46 |

Aurora.—The Aurora mine, situated on the crest of the hill, at the south end and just above the town of Treasure City, is located on another deposit, which is of a different type from that of the Eberhardt. It is wanting still more than the last-named in the characteristic features of a fissure vein, but is rather a course or series of ore-bearing deposits, lying in a north and south or, more nearly, in a north-northwest and south-southeast, direction, along which line there seems to have been a movement or disturbance of the rocks sufficient to crush and crumble them into fragments, but in which movement there are no apparent evidences of a regular, deep-seated fracture, or fissure.

The character of the ore-bearing material is similar to that of the Eberhardt, consisting of brecciated limestone, much of it in small fragments and

highly silicified, mingled with and cemented together with quartz, spar, and ore. Occasionally crystals of free quartz and, more frequently, crystallized calcspar and other carbonates occur. The siliceous limestone, quartz, and spar appear to be impregnated with the finely-distributed silver mineral, but the richest occurrences of the latter are in the fillings of little clefts and joints of the rock, in which are found seams or thin sheets of chloride of silver. Blue and green stains of the carbonates of copper are abundant and are considered as indications of rich ore. The length of the ore-bearing course is traced for hundreds of feet. The Aurora South, at the south end of the crest of the hill and overlooking the southern slope, is 800 feet long; north of that claim is the Aurora Consolidated, comprising 800 feet more; nearly the whole of this ground has been found rich in ore; and beyond this, northward, other claims extend, developed to a much less extent but productive in some places. Its width is not well defined, but the workings cover, perhaps, a hundred feet in an east and west direction. The surface rock is chiefly barren limestone, which lies flatly, dipping slightly to the westward, and usually forming a thin cap over the ore-deposits. The latter, however, sometimes appear exposed at the surface.

The greatest depth reached in September, 1869, was between 50 and 60 feet; and along the claims of the Aurora South and Aurora Consolidated several large chambers, reaching that depth and extending to a greater or less distance longitudinally and laterally, thus forming irregularly-shaped excavations, had been worked out. On the Aurora Consolidated, in the vicinity of the Earl shaft, the limit of the pay-ground on the west appeared to be a "floor" in the limestone, striking north 25° west, true, and dipping north 25° east, at an angle of about 30° from the horizon. This floor or seam was smooth, well defined and regular in course and dip. The pay-rock rested upon it, but apparently did not go below it; where it had been broken through in two or three places the limestone is said to have been hard, massive, and barren. This floor was then regarded as the "footwall of the ledge." A corresponding limit, or hanging wall, on the other side had not been found. In that direction the ore-bodies seemed to have irregular outlines merging gradually into limestone that was either barren or too poor to pay.

At the date above referred to the Aurora South mine was employing some 60 or 70 men, taking out about 50 tons of ore per day, A large quan-

tity of ore was already on the surface awaiting the completion of the company's mill, which has since gone into operation. The assessor's returns show that in the quarter ending December 31, 1869, 2,437 tons were worked, yielding on an average $43 59 per ton, in coin. The Aurora Consolidated mine during the same quarter produced 2,672 tons of ore, that yielded $28 50 per ton. In the figures just given there is a decided falling off in the yield of the rock as compared with earlier returns. There would appear, however, to be large quantities of ore of similar grade, which in the future ought to be mined and milled at a fair margin of profit.

The Flats.—Just west of the Aurora deposits and a little further down the hill are the gently sloping surfaces known as Bromide, Chloride, and Pogonip Flats. The aggregate area included in these locations is about 2,000 feet long by an average width of 600 feet, amounting to about 25 or 30 acres. The deposits of ore present still another type, differing from those already described. The surface consists of limestone, lying in strata that are nearly horizontal, though dipping gently to the westward in most places. The strata are not always well defined, but are somewhat broken and irregular in their bedding; and are cut through by numerous seams and joints that are filled with crystalline minerals, chiefly calcspar, with some quartz. The ore occurs in channels, or pockets, of irregular form and variable extent. Not all the strata are ore-bearing; on the contrary the ore-channels appear to be confined to one, or, at most, to few of the limestone beds. The distribution of the ore-deposits over the area is quite irregular, and in accordance with no law or system thus far apparent. The conditions of their occurrence bear but little resemblance to those that characterize deposits of ore in veins; they are, rather, a network of seams, channels, or chambers that extend themselves horizontally through the bed of limestone containing them, but with constantly varying directions and dimensions. The pay-ground is sometimes limited or separated from poor ground by seams or joints of calcspar or by "floors" in the limestone, but they are as frequently ill-defined, the ore-bearing rock merging into and mingling with the barren rock, without any apparent line of demarkation.

In their mode of origin these deposits may have a close resemblance to those of regular veins, for the breaks and fissures that traverse the region may have been the channels through which ascended from below the vapors or

solutions or other agents that have deposited or caused the formation of the quartz, spar, and metal-bearing mineral, in manner similar to that by which it is believed that fissures have been filled; with the difference, in this case, that the operation of these influences have extended laterally into certain beds of limestone, the composition or character of which rendered them especially subject to such an action.

On the Genesee, one of the claims on Chloride Flat, is an east and west seam, 3 or 4 feet wide, descending vertically, on which a shaft has been sunk over 100 feet. This shaft was closed at the time of the writer's visit, and was inaccessible. The work is said to have shown a regular break or fracture in the limestone beds, and to have furnished ore throughout its entire depth, but not in quantity sufficient to pay as well as the surface deposits, and it was therefore abandoned.

All the ore produced on the Flats, up to the time of the writer's visit, had come from within 20 or 30 feet of the surface. Deeper shafts had been sunk through the bedded limestone, all of which, with the exception of the Eclipse shaft, were reported to have been unsuccessful in finding ore at greater depths. The Consolidated Chloride Flat Company had sunk a shaft to the depth of 140 feet, which passed through distinctly stratified limestones, lying in beds from 4 to 6 feet thick, nearly flat, but sometimes dipping slightly, showing numerous seams of spar in and between the strata, but without a trace of ore below the surface deposits.

The Eclipse shaft, a little further north and near the edge of Bromide Flat, was sunk with the same view of exploration, and, at the depth of 112 feet, a bed of ore-bearing limestone is said to have been struck, resembling, in many respects, the stratum near the surface, except that the ore was less pure, the silver being associated with baser metals. A few feet had been drifted on this bed at the date referred to, but no extensive or decisive developments had been made. Nine tons of ore are said to have been produced from this stratum, near the bottom of the shaft, that yielded $116 per ton.

The Flats are covered by hundreds of mining claims, that have been located under the laws which were devised and intended to apply to veins, and the attempted application of such laws in the present case, where no veins exist, has, of course, produced a great conflict of interests. Within an area

800 feet square, in the region of Chloride Flat, there were nearly 250 independent locations, most of them claiming 1,000 feet in any direction assumed as the course of the vein, which, in practice, means any direction in which ore can be found. Nevertheless, considering the opportunity thus afforded for quarrels, there has been comparatively little difficulty, and opposing interests have been settled with less frequent resort either to violence or litigation than might have been expected. The claims have usually been located, and at first worked, by men who had no other capital than a few tools and their own muscle, and, if fairly ejected from one claim, they needed only to remove a short distance and resume operations on another streak of ore, the benefit of which they could enjoy until some older claimant could establish his title.

Consolidated.—More recently some large companies have been formed, and many claims have been consolidated into one. The Consolidated Chloride Flat Company is one of the most important of these, having gained, by original location, compromise, and purchase, title to a large area, perhaps 1,000 or 1,200 feet square. This association has been carrying on extensive mining operations in this field during a year past. In September, 1869, there were employed about 125 men in the works of this company, producing about 40 or 50 tons of ore per day. There are two mills, belonging to the company, situated below Hamilton, to which the ore is hauled, in wagons, for milling.

The writer is indebted to Mr. John E. Plater, one of the officers of the company, resident at the mine, for the following statement of operations, which shows the quantity of ore produced from month to month, its assay value and yield per ton, total yield and percentage of its value obtained.

*Operations of the Consolidated Chloride Flat Company from the date of organization to February* 1, 1870.

| Month. | Tons of ore produced. | Assay value per ton. | Yield per ton. | Total yield. | Per cent. obtained. |
|---|---|---|---|---|---|
| 1869. | | | | | |
| May | 381 | $132 50 | $107 80 | $41,007 07 | 81.2 |
| June | 550 | 106 75 | 85 68 | 47,124 97 | 80.2 |
| July | 900 | 74 86 | 52 25 | 47,028 26 | 70.0 |
| August | 1,100 | 56 77 | 42 59 | 46,849 79 | 75.0 |
| September | 1,000 | 57 46 | 44 13 | 44,130 26 | 76.8 |
| October | 740 | 45 26 | 34 32 | 25,394 01 | 75.8 |
| November | 750 | 45 27 | 31 70 | 23,773 47 | 70.0 |
| December | 1,450 | 40 46 | 28 10 | 40,729 11 | 69.6 |
| 1870. | | | | | |
| January | 1,775 | 40 36 | 33 65 | 59,732 64 | 83.4 |
| | 8,646 | - - - | Av., $43 46 | 375,769 58 | |

The total costs of mining and milling the above mentioned 8,646 tons of ore amounted to $254,884 73, giving an average cost per ton of $29 48, which leaves a margin of $13 98 per ton, between the yield of the ore and the cost of producing and milling it. The mining cost, alone, was $14 88, and the milling cost, including hauling, $14 60 per ton.

Hidden Treasure.—The Hidden Treasure is one of the best known and most important mines of the region. The deposit or ledge on which it is located was the first discovered of all those that have made White Pine famous. It is at the north end of the crest of the hill, and on the east side of the ridge, just overlooking Applegarth Cañon. The claim, located as a ledge, is 600 feet long. The mode of occurrence of the ore is suggestive of a contact vein, as the deposits are at the junction of the limestones and overlying slates, which are here conformably stratified, striking in a northerly direction and dipping flatly to the westward. The ore-seam, where distinguished, appears to be from 2 to 4 feet wide on the average, but sometimes expanding to 15 feet. The deposits have been stripped along the length of the claim, and the mine is also opened by a tunnel at the east end. The ore produced in early days was wonderfully rich. According to the returns of the county assessor there were

$211\frac{637}{2000}$ tons of ore obtained from this mine during the quarter ending September 30, 1868, which yielded \$1,140 60 per ton, currency, or over \$800 per ton, in coin. Since operations have been carried on more extensively the average yield of large quantities of ore has been between \$50 and \$60 per ton. In the last quarter of 1869 the original Hidden Treasure produced, according to the assessor's returns, 965½ tons, yielding \$51 78 per ton. The extensions, or adjoining claims, on this ledge have also been somewhat developed, producing some rich ore, and sharing the reputation of the original location.

Sufficient has been already said to indicate the main features of the ore-deposits on Treasure Hill, and to show the different forms in which they occur. It will be needless to enumerate here all the other claims or mining properties whose operations have made them locally celebrated. Some of them are important and extensive, contributing largely to the bullion production of the country. Such is the Treasure Hill Mining and Milling Company, working the Summit and Nevada and the Iceberg claims, located near the Aurora deposits and on the Flats, and possessing characteristics similar to those described already. The company just named, during the last quarter of 1869, produced from the three claims 2,445 tons of ore, yielding \$43 per ton.

Many of the claims in Mahogany Cañon were being worked in September, 1869, and promised to be of much importance. The California, on the southwest slope, was also regarded as one of the important mines of the region. The average cost of mining is probably fairly indicated by the statement of the Consolidated Chloride Flat Company, given on a foregoing page. According to this it amounts to nearly \$15 per ton. Doubtless there are mines or small claims, the conditions or circumstances of which permit the extraction of the ore at a much lower figure, while in others the cost will be a good deal higher. In some of the months of 1869 the cost of mining in the works of the company just named amounted to \$20 per ton. Where the work is open to the surface and so situated as to avoid much windlassing or handling of the rock, the expense is diminished; but, in most cases, where operations have become somewhat extensive, the ore is mined in chambers or cavities below the surface, must be broken, assorted, and moved to the shaft or pit, and raised by hand. The irregular form of the deposits prevents such

economical and systematic methods of operation as are available in ordinary mines, and much labor is, therefore, involved in accomplishing the work. Labor costs $4 per day in coin; and this is the chief item of expense. It amounted to $1,260 in one month in the Consolidated Company's works, the product being 900 tons; equal to $14 per ton; besides which the cost of supplies and materials was $1 per ton. The rock is pretty hard and requires blasting. According to Captain Roberts, superintendent of the Aurora Consolidated mine, the cost of mining, per ton, is not less than $12.

There are no steam hoisting works on any of the mines in this vicinity; ordinary hand-windlasses have sufficed for the depths to which mining has thus far been carried. The region is very dry and there is no water to be raised from the mines. The present method of operation requires little or no timbering.

MILLING.—The ores of the Treasure Hill mines are simple in character and are readily worked by the ordinary Washoe process, that is, by pan amalgamation. The silver-bearing mineral is chiefly chloride of silver. They require no roasting and yield a high percentage of their value when carefully manipulated. The general features of the process and of the machinery employed have been already described in the chapter devoted to the subject of milling of the Comstock ores.

Although the chloride ores of White Pine require no roasting some of the mill-men of the district prefer to crush them dry, and, until lately, most of the mills were arranged for that method. The object in this is, or was, to avoid the loss that is involved by wet-crushing, in the washing away of fine particles of rich mineral, that are either swept away by the stream in the form of floating scales, or that are reduced to an impalpably fine condition and are carried off in the slimes, thus escaping the treatment of the pan. This was a matter of much importance in working very rich ore, as the loss of a small percentage amounted to a large sum in actual value; and the increased expense of crushing dry was therefore well repaid. For working ores of lower grade, however, wet-crushing is preferred, on account of its comparative cheapness; and, of late, since the average value of the ores of the district has fallen off considerably, several of the dry-crushing mills are reported to have been re-

arranged for wet-crushing. Some mills have a part of their stamps adapted to dry and a part to wet-crushing, so that either method may be selected according to the character of the ore to be worked.

The ore, after being crushed, either dry or wet, is then worked in pans. These are of the kind already described. Among those in use are Varney's, Wheeler's, Hepburn's, McCone's, and Fountain's. The method of operation, the duration of the grinding and amalgamating process, the "chemicals" used, are generally the same as in the mills about the Comstock. Concerning the use of chemical reagents it may be said that some mill-men use a much larger percentage of salt than is employed in working the Comstock ores, amounting, in some cases, to 2 per cent., or 40 pounds per ton of ore. The necessity for this is not apparent in working ore in which the silver is already supposed to exist in the form of chloride; and it would seem that the use of salt in such proportions is more the result of habit than careful reasoning. The practice appears to have been introduced into the district by men who were accustomed to the working of so-called "rebellious" ores, or those that require to be roasted with a large percentage of salt, as is the case at Austin; and who, though dispensing with the roasting process, retained the use of salt, apparently without much consideration of the necessity of the case. Other mill-men coming from the vicinity of Virginia City adopted the methods in use there, employing two or three pounds of salt and a little sulphate of copper with each charge of ore. According to Captain Rawlings, superintendent of the Manhattan mill, near Hamilton, an increase in the amount of salt used with the ore did not improve the result.

The percentage of the assay value obtained from the ore is shown in the statement of the Consolidated Company's operations. It varies from 70 to little over 80 per cent. In some mills the percentage obtained is said to be still higher, even exceeding 90 per cent., especially where dry-crushing is employed, as in this case there is less mechanical loss by the action of the water and in the slimes. At the Manhattan mill several assays of tailings, made in the month of August, 1869, gave an average value of about $13 per ton. An assay of the slimes at the same time gave a value of $64 per ton.

The bullion produced is generally very fine. The precious metal is sil-

ver only. The average quality of the bars is $\frac{950}{1000}$ to $\frac{960}{1000}$. The Eberhardt mill was producing bullion, at the time of the writer's visit, that was from $\frac{994}{1000}$ to $\frac{998}{1000}$ in fineness.

The average cost of milling has been indicated in the statements already given. The expense of treating 8,646 tons by the Consolidated Chloride Flat Company was $14 60 per ton. This includes hauling, an item amounting in this case to $4 50 per ton. The figures above given are the average of all the ore treated up to February 1, 1870, and the costs in the latter part of the included period were probably little less than the average of the whole, as some items of expense have since been reduced. Moreover, the company had between 200 and 300 tons of their ore worked in custom mills, at high prices, which would slightly increase the average of the whole.

In the month of August, 1869, the cost at the Manhattan mill was $12 34 per ton. The items composing this cost were as follows:

| | | | |
|---|---|---|---|
| Labor | $3,414 25 | or, per ton, | $3 10 |
| Supplies and materials | 5,208 45 | or, per ton, | 4 74 |
| Hauling | 4,950 00 | or, per ton, | 4 50 |
| 1,100 tons, total | 13,572 70 | | 12 34 |

Allowing $4 50 for hauling, this sum is reduced to very nearly the same as that shown to be the cost of milling at Washoe in some steam mills. Labor is rather higher than at Washoe, and in the Manhattan mill, from which these figures are obtained, more men are required in handling rock than are usually employed at the Washoe mills. This is due to the want of a rock-breaking machine, a suitable dump for the ore, and convenient arrangements for fuel. Thus, the men employed were: 5 rock-breakers, 3 feeders, 3 amalgamators, 2 retort men, 3 wood-wheelers and passers, 2 firemen, 2 engine drivers, 1 carpenter, 1 watchman, 1 foreman; in all 23.

The price of this labor is from $4 to $6 per day. The company own a boarding-house and board their men. In the Eberhardt mill, where the men are paid without board, the prices were as follows:

| | |
|---|---|
| Chief engineer, for two mills | $8 00 per day. |
| Engine drivers | 6 00 per day. |
| Pan men | 5 50 per day. |
| Feeders | 4 50 per day. |

Castings are also more expensive than in Washoe, as is, indeed, everything else in which freight is an important element of the cost. Salt costs three cents per pound. Fuel is generally supplied to the mills of the district at $5 50 to $6 per cord. It is of fair quality, consisting of pine, cedar, and mountain mahogany.

Water is derived by some mills from springs near which they have located. To others it is supplied by the White Pine Water Company; the price in this case was, at last accounts, $1 per day, per stamp supplied. At this rate the cost for water would be from 50 cents to $1 per ton, according to the capacity of the stamp.

The following is a list of the mills that were in operation, or nearly completed and ready for work, in the neighborhood of Treasure Hill, about the end of September, 1869. The capacity of each mill is indicated nearly, but cannot be stated exactly. It depends on whether the crushing be wet or dry, on the character of the ore, size of the screen, and various other conditions that may vary in the same mill at different times. The figures are inserted in the column partly from the statements of the managers of the mills, partly from estimate.

*Crushing Mills in the vicinity of the Treasure Hill Mines, September,* 1869.

| Name of mill. | Locality. | No. of stamps. | Method of crushing. | Number of pans. | No. of settlers. | Capacity—tons per day. |
|---|---|---|---|---|---|---|
| Manhattan - - - | Below Hamilton - - | 24 | Wet - - | 16 Varney - - | 8 | 40 |
| Dayton - - - - | Below Hamilton - - | 20 | Wet and dry | 6 McCone - | 4 | 30 to 35 |
| Treasure Hill Mining and Milling Co. | In Hamilton - - - | 20 | Wet - - | 6 Fountain - | 4 | 35 to 40 |
| Miller's - - - - | In Hamilton - - - | 10 | Dry - - - | 6 (4 Varney) - | 2 | 10 |
| Murphy's - - - - | Applegarth Cañon - | 5 | - - - - | - - - - - - | - | 8 |
| Nevada - - - - | Applegarth Cañon - | 10 | Wet - - | 3 McCone - | 3 | 20 |
| Henderson - - - | Applegarth Cañon - | 7 | - - - - | - - - - - - | - | 10 |
| Treglone - - - - | - - - - - - - - | 10 | - - - - | - - - - - - | - | 15 |
| California - - - - | Eberhardt City - - | 30 | Dry - - - | 16 Wheeler[2] - | 8 | 40 to 50 |
| Moyle & Sears - - | Near Shermantown - | 5 | - - - - | 2 - - - - - | - | 5 |
| Kohler - - - - - | Near Shermantown - | 8[1] | - - - - | - - - - - - | - | 5 to 10 |
| Metropolitan - - - | In Shermantown - - | 15 | Dry - - - | 10 Hepburn[2] - | 5 | 20 to 25 |
| Eberhardt - - - - | In Shermantown - - | 10 | Dry - - - | 10 Varney - - | 3 | 12 to 15 |
| Eberhardt, 2d - - - | In Shermantown - - | 8 | Dry - - - | 4 Wheeler - | 2 | 7 |
| Vernon - - - - | Swansea - - - - | Crusher | - - - - | 1 Hepburn - | - | 5 |

[1] Howland's battery. [2] With wooden rim.

In addition to the mills above named may be mentioned the Monte Christo mill, 12 or 14 miles distant, containing five stamps; and the Newark or Centenary mill, in the Newark district, 30 miles distant, containing 20 stamps. The last-named mill is also provided with roasting furnaces. Both these mills worked on White Pine ore before others were built nearer to the mines.

Among the mills named in the foregoing table are several that were brought from other parts of the State, where they had been already in use. Others are quite new and combine, in their construction, many of the improvements that are the results of long experience in milling. The California mill is one of the best in the State, and is very well arranged for economy in labor. The mill stands on sloping ground, and is so laid out that the ore, in passing from one stage of the process to the next, has the advantage of gravity, and is moved with the least possible outlay of power.

The ore is carried into the mills by the wagons that bring it from the mine, and is dumped upon a paved floor, several feet below the platform on which the wagon stands, so that there is space sufficient for a large accumulation of rock. Thence it is passed through a Varney and Rix crusher, the mouth of which is even with the floor. From this it is delivered upon a drying floor, consisting of flues covered by boiler plate. The area of this floor is 10 by 48 feet, with a firing-place at each end. When sufficiently dry for stamping the ore is shoveled into cars, standing on a track on a lower floor, so that their upper edges are below the drying floor. These cars, when full, are then moved forward to the batteries, where they serve as hoppers to supply the ore to the stamps, as the front end of each car is provided with the self-feeding apparatus. By pushing the car up to the battery and securing it there, by a simple contrivance for that purpose, it discharges its contents gradually into the mortar, according to the rapidity with which the material is crushed. The stamps are 30 in number, arranged in six batteries of five each, with a separate cam-shaft for each two batteries; the stamps weigh 750 pounds, drop 9 inches, making 95 or 100 blows per minute. Screens are No. 40 wire-cloth. The discharge is on both sides of the mortar. The crushed ore is collected in tight chambers that inclose the mortars, and are so constructed as to discharge their contents through sliding or trap doors, and without any shovelling, into cars, by which the ore is carried to the pans. The pans are arranged in two parallel rows, at right-angles to the line of batteries; the car track passes between the two rows of pans, supplying either side. Wheeler's improved pans are used in this mill. The pan-bottom, made with a steam-chamber, is cast without a rim, but has a flange near the periphery, around which the wooden staves are fitted and secured by an outer iron band. Each pan takes one ton at a charge, and works four charges per day. Below and in front of the pan are the settlers, of the pattern known as Belden's; there are eight of these, one for two pans. Beyond these, on a lower level, are the agitators, four in number. There are four retorting furnaces, capable of receiving 1,400 to 1,600 pounds of amalgam, and two melting furnaces. Power is supplied by an engine, 20 inches diameter by 36 inches stroke, to which steam is furnished by two boilers.

Bullion Product.—The bullion product of White Pine, or the mines about

Treasure Hill, from the beginning of operations in the summer of 1868 to the close of that year, may be stated in round figures at $500,000; and during the year 1869 at $3,000,000; making in all, to January 1, 1870, $3,500,000 in coin value. This is based upon data chiefly obtained from the books of the various express companies or forwarding agents, through whose hands the bullion has passed.

| | |
|---|---|
| According to these sources of information there were sent to Austin, in 1868, and worked at the Manhattan mill, 423¼ tons of ore, yielding.. | $135,584 17 |
| And the product of the Newark mill, likewise shipped through Austin.. | 397,475 68 |
| | 533,059 85 |
| Careful inquiry in Austin showed that of the last item, a portion, not exceeding $13,000, was produced by the Chihuahua mine in the Newark district, which being deducted, leaves, say................ | $520,000 00 |
| The express companies in Hamilton, Treasure City, and Sherman commenced shipments late in 1868, and up to September 20, 1869,[1] the aggregate of these amounted to.................................. | 2,381,000 00 |
| Shipped from Newark office to same date........................... | 106,000 00 |
| Making a total to September 20, 1869................................ | 3,007,000 00 |

The statements of the county assessor for the quarter ending December 31, 1869, show a product for the last three months of that year of $537,289 61; which, added to the foregoing, gives an aggregate of over $3,544,000, without taking into account the shipments of the last ten days of September, or the amount by which the actual production of the last quarter may have exceeded the assessor's return. The bullion shipped from the Newark office, and the amount reported by the assessor for the last quarter, include something, probably less than $20,000, derived from the Chihuahua and other mines not belonging to the Treasure Hill group.

This sum total is considerably larger than would appear from the books of the county assessor; but that officer's statements are, probably, never in excess of, and doubtless often less than, the whole product. There are many small quantities of bullion, produced by parties who work on too small a scale

[1] The writer is indebted to Mr. W. T. Childs, of Wells, Fargo & Co.'s office in Treasure City, for aid in obtaining this information.

to attract attention, that escape taxation altogether. These sums are small individually, but may make a considerable amount in the aggregate. They may not be reported to the assessor, but are almost always deposited at the express office; consequently the data obtained from the latter source, if correctly stated, are more likely to express the actual truth.

The following table gives an abstract from the county assessor's books for the year 1869, which, as just intimated, can only be regarded as a partial statement of the product of the district, even during the period referred to. It includes nothing of the product of 1868. The values expressed are in coin.

*Data obtained from the Quarterly Returns of the Assessor of White Pine County, showing the quantity of ore produced by the mines of the district and the yield of the same.*

| Quarter ending— | Number of tons. | Average value per ton. | Total value. |
|---|---|---|---|
| March 31, 1869 | 948 | $278 48 | $263,999 47 |
| June 30, 1869 | 4,174½ | 99 74 | 416,385 85 |
| September 30, 1869 | 10,329 | 58 59 | 605,192 86 |
| December 31, 1869 | 12,947 | 41 50 | 537,289 61 |
| | 28,398½ | 64 19 | 1,822,867 79 |

From the foregoing it appears that the average yield of the ore is falling off considerably from that obtained in the earlier days of operation. There is, however, a fair, and with the gradual reduction that may be expected in the costs of operations, even a large margin of profit in working rock that yields $40 to the ton. The great question is that of the quantity of ore available, or the extent of the deposits, and that can only be answered by actual development.

Base Metal Range.—The Base Range, so called from the nature of its metalliferous deposits, in which lead and other inferior metals predominate, is also regarded, according to late accounts, as an important element in the future of the district. The locality thus designated is a low ridge which lies between Treasure Hill and White Pine Mountain, trending north and south, with a length of two or three miles. It has been prospected within the past year,

and numerous deposits of lead have been opened. At the date of the writer's visit to White Pine none of these had been sufficiently developed to afford very decisive evidence as to their nature and extent.

The deposits then appeared in the form of masses or pockets of ore, distributed irregularly in the limestone. Some of them had furnished considerable quantities of ore, but all from near the surface. The ore consists chiefly of the oxide and carbonate of lead, containing from 50 to 60 per cent. of metal, with an average of 50 ounces of fine silver to the ton of metal obtained.

Several smelting furnaces were built in the vicinity during the past year, most of them being of an experimental character. At Mosheimer's establishment, in Swansea, there are two furnaces, one of which has the capacity to treat 20 tons of ore daily. This is a simple shaft or blast-furnace, built of sandstone that is found in the vicinity, and said to be excellent material for the purpose. The work had not been long in progress, but, according to Mr. Keyes, the metallurgist of the establishment, the average yield of ore, thus far treated, was, as above stated, about 50 per cent. of metal, carrying 50 ounces of silver to the ton. The metal, when obtained, is shipped to San Francisco, where the lead was then said to be worth about $90 per ton, and the contained silver, unseparated, $1 per ounce. Several small lots of lead had been shipped, at the time referred to, amounting in all, so far as the writer could learn, to 25 or 30 tons. Newspaper statements place the value of metal shipped from the Base Range, from the commencement of operations to January 1, 1870, at $50,000.

Fuel and Water.—The supply of fuel in the district has been already referred to. White Pine Mountain and the hills of the surrounding country possess what, for that country, may be considered an abundant growth of timber. Saw-mills are established, and a fair quality of lumber is produced, that sells at about $100 per thousand feet. Fuel is cheap, considering its cost in many other districts of the State, being supplied to mills at $5 50 to $6 per cord.

The supply of water in the immediate vicinity of Treasure Hill is very limited. In some of the neighboring cañons there are streams and springs, affording water to mills located near them; but until the pumping works of the White Pine Water Company began operations, there was considerable

difficulty in obtaining enough water even for domestic purposes, not only in Treasure City, where there is no natural source of supply, but in Hamilton, where it is very scarce.

White Pine Water-Works.—The Water Company, organized in San Francisco with a large capital, projected works on a truly magnificent scale, for the purpose of furnishing water to the towns of Hamilton and Treasure City, and to the mills situated in the vicinity. Their source of supply is a spring found in a cañon on the east side of the range of mountains that is immediately east of Applegarth Cañon. This spring which furnishes an abundant supply, is nearly or quite 1,000 feet below the summit of the pass over which the water must be carried in order to descend into Applegarth Cañon.

To raise the water from the spring to the pass, pumping works of great power and capacity have been built, employing the double-acting Cameron or Stoddard steam-pumps. The steam-cylinders of these pumps are 22 inches in diameter, and 5-foot stroke, and the water-cylinders 10 inches in diameter. The pipe, or column, through which the water is forced is 12 inches in diameter, and made of riveted boiler-plate, in sections 20 feet long, joined together by means of a cast bell and socket joint, that is filled with lead.

The works established at the spring consist of two duplex pumps, either of which has sufficient capacity, allowing one to be held in reserve for emergencies. There are two boilers and all the necessary appurtenances for carrying on the operation.

The water is pumped from this point in a single lift, 470 feet, to a reservoir, where a similar pumping station is established, by which means the water is again raised nearly an equal distance, 465 feet, making 935 feet in all. The column is buried in the ground for protection; the aggregate length, for the two stations, is 10,487 feet.

At the elevation to which the water is raised by the second pumping station there is a capacious reservoir, from which the water is carried through a tunnel, 307 feet long, passing under the crest of the ridge, and opening, on the other side, upon Applegarth Cañon. Thence the water is led down the slope in a 12-inch pipe, descending vertically 420 feet, in a distance of 3,187 feet, near which point the supply for Hamilton and the mills in Applegarth Cañon is withdrawn, the pipe continuing upward on Treasure Hill to a station

400 feet above the lowest depression, and 2,739 feet distant, to which point the water is forced by its own pressure in the inverted syphon. At this station other pumping works are established, using four Martin pumps, and raising the water to Treasure City, 682 feet higher. This is accomplished in a 7-inch pipe. The supply pipes for the towns are 3-inch tubing. The capacity of these works is stated by the engineer, Colonel Buckley, at 2,500,000 gallons daily. The supply at the spring is said to be not less than 5,000,000 gallons. The cost of the works is stated at $300,000 in coin. They commenced running in October, 1869.

Newark District.—The Newark district is 25 or 30 miles north of White Pine, being by that distance nearer to Elko, its point of connection with the Pacific railroad. It was organized in October, 1866, and, until eclipsed by the later developments of White Pine, was the principal mining region in that part of the State. It is on the east slope of the Diamond Range. The principal developments have been made by the Centenary Company, who own claims on several veins, the most important, according to present appearances, being the Chihuahua. This ledge occurs in an outlying spur of the range, in which the limestone strata appear to strike northwesterly, dipping flatly to the westward. The vein has a similar course, but nearly a vertical dip, inclining a little to the westward. Its croppings are very prominent, standing up 30 feet or more above the surface. The vein is from 6 to 15 feet wide, and is filled with quartz and calcspar. The ore, which is usually associated with the former, consists of antimonial and sulphureted combinations of lead, copper, and silver. It requires to be roasted for the extraction of the latter. Its average yield appears to be between $80 and $100 per ton. The ledge and its inclosing rocks are cut through transversely by a deep cañon, which affords a favorable opportunity of working the mine by means of tunnels or adits. Two or three of these have been driven, one above the other, and several hundred feet long. As nearly as could be ascertained by the writer, about 900 or 1,000 tons of ore have been produced, yielding something less than $100 on the average.

The company own a fine mill, situated about three-fourths of a mile from the mine. It contains 20 stamps, 8 reverberatory roasting furnaces, 10 pans, and 5 settlers, driven by an engine of 140 horse-power. It is said to have cost $130,000 in currency. The cost of the mine improvements is stated at $50,000 more.

Of the costs of operation the writer could learn but little. During the White Pine excitement the mill was chiefly employed in working on ore from that district, as the profit, at the prices then paid for milling, was greater than could be derived from the ores of the company's mine. Only a small force was at work in this mine in the summer of 1869.

The country south and east of White Pine, already partly prospected and somewhat developed before the Treasure Hill discoveries attracted general attention, has been more thoroughly examined, within the past year or two, than ever before. Many new districts have been formed, and from some of them the most encouraging accounts are being reported. The writer was unable to visit any of them. Of some of the older districts descriptions may be found in the reports of the United States Commissioner of Mining Statistics.

North and east from White Pine is the Egan district, lying on the old overland road. The principal mine of this region was visited by Mr. S. F. Emmons, whose notes concerning it are added here.

## SECTION VI.

### EGAN CAÑON DISTRICT.

BY S. F. EMMONS.

The Egan Mountains form the first high range east of the East Humboldt Mountains, their highest point attaining an elevation of 10,490 feet above the level of the sea. They are mainly composed of stratified limestone, rich in fossils of the Carboniferous period, and having a general dip to the westward. About fifteen miles south of the latitude of Camp Ruby, and perhaps thirty miles east of that point, the range widens out into two distinct ridges, which extend to the south, inclosing between them a pretty mountain valley, eight or ten miles long, and about a mile wide. This valley is 200 feet above the level of Butte Valley, and about 500 feet above Steptoe Valley, which lie, the one on the west, the other on the east of the Egan Mountains. It gives access to a very considerable amount of timber, with which the surrounding hills are well covered, consisting chiefly of juniper and piñon, useful for fuel, and some yellow pine and fir, which furnish mining and building timber. Besides several springs, the valley has a small stream, fed by the melting of the snow on the high peaks to the southeast, which runs northward along its eastern edge, and finds an outlet into Steptoe Valley through a narrow, precipitous gorge in the eastern ridge at the northeastern extremity of the valley. This gorge is Egan or Gold Cañon, which gives its name to the district; through it the Overland Stage road descends into Steptoe Valley, by which it is about 240 miles from here to Salt Lake City. A road running north through Steptoe Valley reaches the railroad at Toano, about 90 miles distant. At the entrance to the cañon, and on the grassy bottom of the valley just above it, is the little mining town of the same name, 6,379 feet above sea level.

GEOLOGY.—The ridge west of the valley is composed of strata of a bluish-gray limestone, dipping gently west, the regular continuation of the northern portion of the range, while the eastern ridge has an entirely different character, being composed of granite, quartzites, and slates, the latter uptilted

at a steep angle, and having a north and south strike. They evidently belong to an earlier formation than any of the Carboniferous limestones of this region, but their connection with strata of well-determined age has not been traced; no fossil remains have as yet been discovered in them, but they resemble in lithological character the quartzites of the Uintah Mountains in Utah. The granite forms the eastern foot-hills of the ridge, extending for about half a mile up Egan Cañon; it seems to extend further into the hills to the south, and only to form the extreme foot-hills to the north; it is succeeded above by quartzite, which forms steep, rugged cliffs, rising precipitously a thousand feet or more on either side of the cañon. The granite, at the mouth of the cañon, is much decomposed on the surface, and stained with iron oxide, while higher up it is more compact, and contains a large proportion of quartz. There seems to be a regular transition from granite into quartzite, the intervening rock being composed of rounded grains of limpid quartz, in a green, feldspathic paste; the quartzite itself, which is the predominating rock in the cañon, retains this structure in a measure where the feldspar has disappeared, and almost resembles an eruptive rock; it has a massive structure, in which the bedding is still visible, however.

The upper part of the cañon is in slates, which succeed the quartzite and alternate with it; the slaty structure is generally very regular, the laminæ being about half an inch thick; their cleavage planes seem to conform to the line of stratification. The predominating slates are of greenish and purplish colors; the former seem to be a fine-grained mica-schist, while the latter are frequently nothing more than quartzite, with a slaty structure; these have frequently rounded grains of limpid quartz, which give them the appearance of a conglomerate. On the very edge of the upper valley is a small outcrop, about 30 feet thick, of finely laminated, argillaceous slates, which present very beautiful dendritic markings on their surface. These slates split easily into very thin slabs, which are tough and somewhat flexible, and apparently well adapted for roofing slates.

Mineral Deposits.—The first discoveries in this district were of gold, whence it was called Gold Cañon; but no great amount of gold having been produced, it is better known as Egan Cañon, a name derived from that of one of the first explorers of this region, who fixed the present location of the stage

road. A small vein of gold-bearing quartz, high up on the quartzite cliffs on the north side of the cañon, has been worked in a small way by two miners, Mr. Kinsley and his partner. Their ore is a pure, white quartz, showing small stains of iron oxide and occasional specks of free gold. It was broken by hand to the size of a walnut, and ground and amalgamated in a small arrastra, which was run by a small overshot wheel; its capacity was about 500 pounds per diem. The ore yielded by this rude process about $40 per ton.

The main producing vein of the district is the Gilligan, which is in the slates, running across the formation and probably extending into the quartzite. It has a northeast and southwest strike, and dips to the northwest at an angle of 60° to 70°. It crops out a hundred feet or more above the level of the upper valley, on the southeast face of a round-topped hill or spur, which borders the upper part of the cañon on the north. This vein is remarkable for its uniformity, both in size and yield; it averages five to eight feet in width, reaching fifteen feet in some places, and pinching to two and a half feet at one point. While its average yield is about $60 per ton, richer portions go as high as $200, and the second-class ore as low as $40. The ore is a white quartz, more or less broken, and stained by the oxide of iron, carrying sulphurets of silver, and probably some free gold. The bullion produced is .937 fine, and gives, in value, two-fifths gold to three-fifths silver. The vein has been followed and tested, either by surface or underground workings, for a distance of 800 feet, and its croppings traced to a much greater distance. On the surface it shows distinct walls on either side; in the underground workings the hanging wall presents a very handsome and well-defined clay gouge, while the foot-wall seems to lose itself in the country-rock, which is impregnated with quartz to some distance from the vein. This vein is the property of the Social and Steptoe Mining Company of New York, whose claim is 3,800 feet in length. This company was incorporated in September, 1866, with a nominal capital of $2,000,000, being formed by the consolidation of the two companies whose names it bears. It owns, besides the Gilligan ledge already mentioned, a five-stamp mill, at the entrance to the cañon, offices, houses, and school-house in the town; a ten-stamp mill, the frame of which is standing near the lower end of the cañon, while the machinery and stamps, which came from the East, are at Salt Lake City, and likely to remain there; also various wood claims and undeveloped ledges.

The Mine.—The work in the mine has been done slowly and in a small way. The principal shaft, or incline, which was worked by a horse-whim, has been sunk in the vein, following its varying inclination, to a depth of 400 feet. At this depth an influx of water from a spring caused them to abandon the lower works, as they had no pumps; these were filled up even with the 300-foot level with second-class ore, but are now being reopened. On the 300-foot level, drifts have been run 150 feet to the southwest and nearly the same distance to the northeast. In the former the vein has maintained an average width of 5 or 6 feet of good ore throughout, and the hanging wall shown—a clean, polished surface of decomposed slate; the vein is divided into two parts by a thin clay selvage, which runs through its whole length; some two and a half feet toward the hanging wall are of first-class ore, while the remaining three feet toward the foot-wall are second-class ore, which has hitherto been rejected and used for filling up old works. The whole is a mass of iron-stained quartz, so much broken that it can almost be taken out with the pick; occasional spots of soft, black matter, probably resulting from the decomposition of a concentration of sulphurets, are said to be very rich. At the end of the drift a piece of ground about 6 feet high by 15 feet long has been stoped out above the gallery. In the northeast drift the vein pinches to about 2½ feet; at a distance of 100 feet from the shaft the quartz becomes whiter and more compact, but it opens out again at the face, and shows the same character of ore as in the other drift. From this level to the surface are no other workings; the incline is said to have been in good ore, and in the same width of vein throughout its length. Just at the surface, to the northeast of the shaft, a small body of ore has been stoped out, which yielded in the mill $18,000, being an average of $200 to the ton. This incline was originally so narrow and crooked that its extracting capacity was very limited, and it was found necessary to enlarge and straighten it. This work was commenced in March, 1868. As it now stands the shaft has two hoisting compartments and a ladder-way; it is well timbered and ceiled with two-inch stuff. To the northeast of this shaft, at a distance of about 150 feet, a prospecting shaft has been sunk to a depth of 75 feet on the vein, and said to be in good ore; at a distance of 300 feet, in a re-entering angle of the hill, a second shaft is down to the 300-foot level, which it is designed to connect with the main shaft and use as an air-shaft; in it the vein averages about 8 feet wide, and is

said to yield well, though the quartz, whiter and more compact, does not look as rich as that in the main works.

To the southwest of the main shaft a trench has been dug, stripping the vein to a distance of 500 feet, thus passing a change in the formation from quartzite into slate; the yield was good all the way, and gave more gold after coming into the slates. A good grade leads down from the main shaft to the mills.

MILLS.—The old mill is situated just above the town on the banks of the stream which runs out through the cañon. It is a small frame building, with blacksmith shop attached; has for motive power a small steam-engine of 8-inch cylinder, which runs, besides the machinery of the mill, a small circular saw on the outside, used for sawing mining and building-timbers. It has a battery of five stamps, weighing about 650 pounds each; these stamp dry, and the pulverized ore is carried from a battery to a dust-chamber above by a fan blower, which makes about 2,500 revolutions per minute; they claim by this means to save much dust. The ore is ground and amalgamated in three Varney pans and two settlers, which have a capacity of about five tons per twenty-four hours, though the crumbly nature of their ore would permit them to stamp more. Wood, as fuel, costs, laid down and corded at the mill, $3 50 per cord. For timber they obtain from the neighboring hills fir and yellow pine.

Mr. O'Dougherty, the superintendent, states that from the first opening of the mine to March, 1868, the running expenses have been paid by what they have been able to crush in this mill, which has yielded in all about $80,000 bullion. Since that date the mill has been idle, as no ore could be extracted while the repairs on the main shaft were going on. At the present time, September, 1869, the company is building a 20-stamp wet-crushing mill with large pans of the best approved models, whose capacity may be doubled if the supply of ore demands it; they expect to reduce the ore at a cost of $12, coin, per ton, including mining expenses, and calculate on an average yield of $40 per ton, from the whole vein, which would give a very handsome profit from the amount of ore now in sight. The mill is to be finished during the fall, and the steam hoisting works of the main shaft are already in running order.

# CHAPTER VII.

## THE GREEN RIVER COAL BASIN.

The Great Basin is bounded upon the east by the Wahsatch Mountains, a definite, single range vieing in altitude with the Sierra Nevada. Along its western base lie the deepest plains of Utah, sinking to the level of 4,000 feet, and occupied by low desert ranges, wide expanses of alkaline desert, and saline lakes, of which Great Salt Lake is the largest and best known. Those low mountain chains which lie traced across the desert with a north and south trend, are ordinarily the tops of folds whose deep synclinal valleys are filled with Tertiary and Quaternary detritus. They are composed of sedimentary beds, dating from the Azoic up to the late Jurassic. It is common, however, to find no rocks higher than the Carboniferous, for immense erosive action has gradually removed the uppermost members of the series of tables, the Carboniferous limestone offering sufficient resistance to the weathering forces to protect the lower members of the group. The Wahsatch itself is one of the most important mountain ranges of America. Its summits tower to the region of perpetual snow and its bases are cleft down sometimes to the level of the Utah plain. Cañons of extraordinary abruptness are water-carved transversely through its rock material, opening with bold, picturesque gateways upon the level of the Mormon lowlands. The materials of this range are in general identical with those of the other great Cordillera chains, but they are here developed and exposed on a scale of grandeur and clearness of relation which is nowhere else apparent. Fifty-six thousand feet of conformable stratified rock make up its bulk. A lower group is composed of about 25,000 feet of intercalated quartzose, mica, and hornblendic schists. The quartzites at the uppermost limits of the group arrange themselves in finely stratified layers or solid beds of extreme thinness. Overlying these is a series from 3,000 to 4,000 feet in thickness, embracing representatives of Silurian, Devonian, and Carboniferous periods, eight-tenths of this Paleozoic group being composed of calcareous and dolomitic materials, but interrupted during their lower half by intercalated

beds of quartzite and rough grit. A more minute subdivision of this group is carefully discussed in the earlier volumes. Overlying these limestones is the Triassic series, composed through the lower two-thirds of quartzite, passing upward into fine siliceous limestones, and finally into heavy beds of dolomitic limestones 1,800 feet thick. Above this and closing the Triassic series are further developments of siliceous lime-beds, capped by very typical red sandstone, which forms an excellent datum-point in a description and study of the whole region. Overlying this again are alternate limestones and quartzose beds, which are here and there replaced by argillaceous and calcareous strata, forming a group in which lime, clay, and sand mingle themselves in extremely varied proportions. With these the conformable group ceases, and here the rock of the old Wahsatch Range may be said to end. To the west no others are superimposed upon their bases, but upon the eastern side a series of Cretaceous and Tertiary deposits are laid down unconformably.

From the Wahsatch to the Sierra Nevada there is no evidence of marine rocks subsequent to the Jurassic. Indeed, the whole great basin is a system of folds of the infra-Jurassic rocks, whose accidental depressions and whose broad, continuous synclinals are more or less filled with the fresh water Tertiary deposits, which indicate a former system of fresh-water lakes. Nowhere along the west side of the Wahsatch has any trace of Cretaceous formations been found. The only beds more recent than the Cordillera group are certain calcareous and sandy strata, in which are found large quantities of fresh water fossils, both of mollusks and vertebrate life. The mammalian remains indicate a fauna similar to, if not identical with, that which has been so thoroughly described in the papers of Meek, Hayden, and Leidy on the Niobrara and White River formations. Besides these are a few stratified, volcanic deposits, chiefly tufas of the Rhyolite and Trachyte periods. Subsequently to those nothing is found, except the Quaternary deposits, which, over the whole west, mark the post-glacial erosion.

The Wahsatch, then, is the dividing line between the Central and the Atlantic geological systems. It was the westward barrier to the Atlantic Cretaceous formation. The ocean, during the Cretaceous, so far as we know, never penetrated that region which is called the Great Basin. The rocks of that period are made up of about 9,000 feet of cream-colored and buff sandstones

and calcareous grits. They are chiefly composed of fine, siliceous sand, containing here and there finely comminuted micas, and interrupted at frequent intervals by zones of conglomerates, whose well-rounded pebbles of metamorphic rocks point for their origin unquestionably to the strata of the Wahsatch. Near the summit of the 9,000 feet, a looser texture begins, and this change is rendered very noticeable by the introduction of beds of coal, which, for an unknown distance upward, probably several thousand feet, reappear through a zone of constantly changing sand and mud rocks. The fossil life, which clearly indicates a Cretaceous age for the deepest members up to and including the first two or three important coal beds, from that point gradually changes with a corresponding alteration of the sediments, indicating a transition to a fresh-water period. The coal continued to be deposited sometime after the marine fauna had been succeeded by fresh-water types. The species of fossils are in no case identical with the California Cretaceous beds, which occupy a similar geological position on the west of the Sierra Nevada. Their affinities decidedly approach those of the Atlantic slopes, while the fresh-water species, which are found in connection with the uppermost coal beds, seem to belong to the early Tertiary period. We have then here the uppermost members of the Cretaceous series, laid down in the period of the oceanic sway, and quite freely charged with the fossil relics of marine life; then an uninterrupted passage of conformable beds, through the brackish period up, till the whole Green River Basin became a single sheet of fresh water. The area and boundaries of this great Tertiary lake, which, by the gradual depression of the Mississippi Valley, was drained of oceanic waters, is fully discussed in the geological volumes of this Report. It is only the purpose of the present chapter to indicate the general relations of the coal-bearing series to the rocks which immediately preceded, and those which have been laid down subsequently.

The chain of Uintah Mountains which, in latitude 41°, starts from the crest of the Wahsatch Mountains and projects eastward for certainly 150 miles, making a right-angle with the Wahsatch system, belongs, like all the greater ranges, to the Jurassic upheaval. Its great height lifted a broad, central zone above the level of the Cretaceous ocean. Upon both of its flanks, up to an altitude of 7,000 feet, repose unconformably the buff sandstones and the

mud rocks of the coal series. In the basin of the Uintah, which lies south of this range, the parties of this Survey penetrated but a short distance, yet their explorations were sufficient to develop the fact that the coal strata were present over a very large area, extending indefinitely southward and east. The thickness of the Cretaceous formation is as great as that north of the range. Since, however, no roads penetrated this region, it must be a very long time before settlements shall be founded there, and consequently the coal strata were not studied in great detail.

Subsequent to the laying down of the whole Cretaceous system, and of those conformable fresh-water beds which close the coal-bearing period, another era of mountain uplifts occurred, folding the coal series into broad, undulating ridges, having a general trend of northeast. From evidence hereafter to be assembled it is clearly shown that the coal series were still submerged beneath the fresh-water lake when the mountain uplift took place, and that upon the flanks and summits of this series of northeast Cretaceous-Tertiary mountain chains was deposited an unconformable sediment, which gradually filled all the anticlinals, and at last buried the whole folded system beneath an immense accumulation of horizontal sand and clay beds.

In connection with the period of volcanic outbursts which were subsequent to the laying down of these latest horizontal strata, a third orographical throe took place, which lifted the fresh-water horizontal beds, tilting them to an angle of 15° to 20°, and throwing them into broad and gentle undulations wherever they lay in the neighborhood of the older ranges, such as the Wahsatch and Uintah. Shortly after the volcanic period, the Green River Basin became drained, and a net-work of river systems defined itself down to the center, focusing in the Green River, which longitudinally drains the whole elliptical basin. Erosion thereafter carved away a vast amount of the uppermost Tertiary series, laying bare the undulating folds of the coal rocks.

When the topographical maps of this Survey are completed, the minute details of the Cretaceous folds and of the fragmentary mass of the overlying Tertiaries, which erosion has left upon their flanks and summits, will be carefully laid down. For the present purpose, however, it is only necessary to indicate the main outlines and geographical distribution of three rock sys-

tems: first, those old Cordillera beds which have been folded up into the prominent ranges of the Wahsatch and the Uintah; secondly, the coal-bearing group of Cretaceous and Tertiary rocks, which lie in broad, gentle folds; and thirdly, that series of Green River Tertiaries, as we propose to call them, which, over the greater part of the basin, are still in an undisturbed position, but which, in the neighborhood of the Wahsatch and Uintah, are slightly tilted and thrown into a state of gentle curvature.

Two points in the geology of this region are of the utmost importance: First, the identity of those conglomerate and arenaceous beds, which, along the eastern flank of the Wahsatch, overlie the Cretaceous folds with those horizontal deposits with which the whole plain of the Green River Basin is at present covered; secondly, the entire nonconformity between this series and the underlying, folded, coal-bearing series. Whatever may be the relations of these beds in other places, it is absolutely certain that within the region lying between the Green River and the Wahsatch, and bounded on the south by the Uintah Range, there is no single instance of conformity between the coal beds and the horizontal fresh-water strata above them. The disturbances of the latter series are confined to within 15 miles of the Wahsatch itself, and where they and the coal series are uplifted together the discrepancy of the angle has a minimum of 11° and a maximum of 45°. Actual tracing of the continuity of strata has proven that the uppermost beds of this region stretch uninterruptedly from the Wahsatch to the east side of the Green River; as they lie further and further from the Wahsatch and Uintah, which are in reality the sources of supply of their material, they become finer and finer, the deposits of gravel and conglomerate die out, and the series is composed of an uninterrupted group of sand, marl, clay, and silt beds. The fresh-water origin of these strata is clearly seen from the fossil life they inclose. Mollusks, testudinata, and mammalian remains indicate clearly that they belong to the great fresh-water Miocene series, of which the White River is the type. It is only, therefore, where these superimposed Miocene beds have been eroded that the coal series is discovered. It first makes its appearance in East Cañon Creek, a tributary of the Weber, which flows from south to north, joining the stream in Morgan Valley. Here, rising

against the Wahsatch with a strike which shows it to have been affected by the Uintah mass, lies a series of from 8,000 to 9,000 feet of argillo-arenaceous strata, containing large quantities of marine fossils which will be hereafter noticed. This group is bounded on the west by the Wahsatch, and on the north-east and south by the fresh-water Tertiaries which overlie it unconformably. The Weber River itself makes the next important exposure of the rocks. Where it leaves the mountains and turns northward, flowing through Kansas prairie, it cuts through the coal series, exposing about 6,000 feet of similar buff sandstone beds, having a strike nearly due east and west, with a dip of 35° to 45° to the north. Continuing down the Weber River a flow of the trachytic lava has buried the series upon the left bank, and the overlying Tertiaries mask it upon the right. But the stream bed itself, wherever the underlying rock is not covered by accumulations of more modern detritus, lays bare the characteristic cream-colored sandstone. In this exposure are two or three important beds of coal associated with black, pasty, clay zones of carbonaceous sand material, fine seams of argillaceous mud, and quite a development of marine fossil plants. Continuing still further down the Weber, important masses flank the valley on either side, rising to 800 feet on the west, where they pass under the immense mountain mass of horizontal Tertiary conglomerate. To the east they are laid bare for ten or twelve miles by lateral cañons which have been eroded across their upheaved beds, opening an excellent point of observation both of the nature of the materials and their stratigraphical arrangement. At this point (Coalville) and about 2,000 feet below the summit of the series, occur several beds of coal, associated with the same sands and clays, and accompanied by important deposits of marine mollusks. From Coalville to Echo they flank the road on either side, but on nearing the mouth of the Echo Cañon they pass under the red Tertiary conglomerates, which stretch northward in an unbroken continuance for many miles. Near the head of the Echo Cañon itself the coal series again outcrops, and here is a most interesting instance of the nonconformity of the series, the cream-colored coal rocks plainly underlying the red conglomerates, with a difference of dip amounting to 25°. Passing to the east these beds are found to outcrop again in the region of the town of Wahsatch, and at the Bear River, whose west bank is chiefly formed of the upturned coal series, for eighteen miles

below the railroad crossing. Medicine Butte, a prominent mountain rising about the level of the Tertiary plains, is an anticlinal mass of the coal fold.

After a careful laying down of all known outcrops, with their dips and strikes, it has been found that the system within the limits of this survey consists of three broad folds, having their rise at the base of the Wahsatch, and continuing quite parallel to an indefinite distance, with a course of north 26° east. Of these three folds the central is the most important. Its average breadth is about twelve miles upon each side. The broad, general anticlinal is fluted in minor waves. Near the west are seen the relics of another fold, the synclinal between these two being occupied for a considerable distance by the cañon of the Weber. The curious outcrop known as the Needle Rocks, just below Echo City, belongs evidently to the easterly slope of this fold, and the rocks seen up Lost Creek indicate its further continuance in that direction. So far all the coal mines of any importance belong either to the central fold or to the minor corrugations of its sides. Coalville, the Winship beds, Bear River, and Evanston are all a part of this central fold system. Its further continuance is indicated in the central mass of Medicine Butte. Erosion has not only removed a large part of the superimposed Tertiary series, but it has carved away very much of the fold itself, laying bare strata which belong to its greatest depths and exposing freely the coal which belongs certainly 2,000 or 3,000 feet from its summit. From Bear River City to Green River there are no important outcroppings of the formation. Those sandstones which crown the "Quaking Asp" divide may possibly belong to it, but if so their relations with the later Tertiary have decidedly changed, passing from different planes to entire conformity. On the east side of the Green River the coal series reappears, and occurs with more or less continuity quite through Wyoming Territory and Colorado. The division east of the Green River has been worked up by Dr. Hayden, and also is well treated in the report for the benefit of San Francisco capitalists, by Messrs. Ashburner and Janin, mining engineers.

Our knowledge of the formation is now so well advanced that it can be said with perfect safety that the series contains a practically inexhaustible supply of coal. Beds from 7 to 25 feet in thickness are discovered at intervals over 500 miles, and from their ordinarily gentle dips may be mined with

unusual ease. The mode of ownership of these claims is in an unsatisfactory condition. No surveys have yet clearly defined what part of the public domain belongs to the Pacific Railroad Company, and which are the alternate sections, so that the holders of coal land have only a possessory title, liable hereafter to be displaced whenever a survey shall demonstrate the ownership of the Railroad Company. That corporation makes it a point to lay claim to every available mine within the extreme limits of the national land grant. A few of these claims were discovered before the railroad land was withdrawn from market. Such are those claims in the region of Coalville, which were all taken up under the pre-emption act by Mormon settlers prior to the approach of the railroad. The land policy, however, of the Mormon Church having been arbitrary and peculiar, it is difficult to say where the final ownership of these lands is vested. The paradox of a community claiming land under a government against whose laws they rebel, casts a shadow over all their titles. In case their ownership is denied by the government, the lands become again open to pre-emption, but subject to the conditions of the railroad grant, and it is more than probable that a large number of the important claims would fall into the possession of the already overloaded monopoly. Between the Mormons and the railroad company only a few plucky prospectors have been bold enough to open and hold mines, and they have been careful as quickly as a good exposure of coal was assured to sell out and realize as rapidly as possible. Until a survey is made defining clearly the possessions of the Pacific Railroad Company, or else an act is passed by Congress declaring the whole belt open to pre-emption, no thorough development can be applied to the coal system. The labors of this Survey, however, define very clearly the geographical distribution of all the uncovered portions of the coal series, wherever they occur within its limits.

Upon the geological map of the region east of the Wahsatch, in the Atlas accompanying Volume I, the three prominent formations, with their constantly changing relations to the coal series, will be found fully laid down.

The following interesting communication by Professor F. B. Meek expresses in decided terms the data upon which the lower coals are referred to the Cretaceous and those which prove their gradual transition into the fresh-water Tertiary horizon:

## LISTS OF FOSSILS FROM UTAH, WITH SOME NOTES.

BY F. B. MEEK.

*Specimens from Chalk Creek, two miles above Upton.*

No. 1. OSTREA, (undetermined species.)

No. 2. INOCERAMUS ...................... A gibbous equivalve species, higher than long, with anterior side very short and vertically truncated; and hinge line short and ranging at right angles to vertical axis of valves.

No. 3. INOCERAMUS ...................... A more oblique species. Same found by Captain Simpson on Sulphur Creek.

No. 4. CARDIUM CURTUM, M. & H. ....... The original type was found by Captain Reynolds's expedition on Gros Ventres River. It was also found by Captain Simpson's expedition on Bear River, Utah.

No. 5. MACTRA, (SPISULA?) ............. A beautiful species, apparently of this genus, with regular concentric striæ and furrows.

No. 6. MACTRA, (SPISULA?) ............. Appears smooth, but may be the last with markings gone.

*From Chalk Creek.—B, above coal.*

No. 7. CARDIUM CURTUM, M. & H. ....... (Same as No. 4.)

No. 8. MACTRA, (SPISULA) .............. Like No. 5, but more finely striated and compressed.

No. 9. One or two species of more orbicular, compressed bivalves.

No. 10. ANCHURA?

No. 11. LUNATIA? ...................... Perhaps two species.

No. 12. TELLINA?

*Coalville.*

No. 13. OSTREA ........................ Appears same as No. 1, and like *O. appressa*, Gabb.

No. 14. CORBULA ....................... The cast has the form of *C. pyriformis*, Meek.

*From Water Tank, two miles east of Coalville.*

| | | |
|---|---|---|
| No. 15. | CARDIUM | Like *C. curtum*, and may be the same. |
| No. 16. | MACTRA ? | Same as No. 6. |
| No. 17. | ANCHURA | Same as No. 10. |

*From Echo Cañon.*

| | | |
|---|---|---|
| No. 18. | INOCERAMUS | Like No. 2, but may be different. |
| No. 19. | CARDIUM CURTUM ? | |

*From East Cañon.*

| | | |
|---|---|---|
| No. 20. | MACTRA | A cast, with much the form of No. 6. |
| No. 21. | MACTRA ? | Same as No. 5. |
| No. 22. | MACTRA | Apparently the same as Nos. 6 and 16. |
| No. 23. | SCROBICULARIA ? | |
| No. 24. | TELLINA ? | |
| No. 25. | ABRA ? | |
| No. 26. | CARDIUM | Appears to be a young *C. curtum.* |
| No. 27. | CUCULLÆA. | |

*From Grass Creek, above coal.*

| | | |
|---|---|---|
| No. 28. | OSTREA | A very narrow, straight, elongated species. |
| No. 29. | CARDIUM CURTUM, M. & H ? | See Nos. 4, 15, and 17. |
| No. 30. | MACTRA ? | Same as 16 and 21. |
| No. 31. | SCROBICULARIA ? | Very similar to 23. |

*Tie Siding.*

| | | |
|---|---|---|
| No. 32. | OSTREA | Same as No. 28, apparently. |
| No. 33. | OSTREA | Subcircular. |
| No. 34. | CORBULA | Has the form of *C. pyriformis.* |
| No. 35. | MACTRA ? | A regularly striated species, like No. 5, but shorter. |

CLARENCE KING, ESQ. :

DEAR SIR: I have examined, with as much care as time has permitted, the fossils collected by you and your assistants from the whitish coal-bearing sandstone at the several localities in Utah, mentioned above, and respectfully submit the following note on the same :

In the first place it is proper to remark that they are nearly all merely

casts of bivalve shells, in sandstone, and consequently not in a good condition for satisfactory determination. Indeed, in many cases, they cannot be referred with confidence even to the proper genera, as none of the specimens show the hinge or internal characters. So far as I have yet been able to determine, they seem to be mainly undescribed species. Taken collectively, as a group, they present much the general *facies* of the fauna of the upper members of the series in California referred by Professor Whitney and Mr. Gabb to the Cretaceous epoch. Yet, after a careful comparison with the figures and descriptions given in the California reports, I am not *quite* sure that any of them are really identical with those of the Pacific slope. Nor am I *entirely* satisfied that any of them are identical with any of the forms hitherto brought from the Upper Missouri country, though some of them may possibly be found to be the same as some of the neglected and undeterminable casts we have had from the upper branches of the Missouri.[1]

With the exception of the genus *Inoceramus*, which is certainly represented by two or three species, and perhaps *Anchura*, all of these fossils, so far as their characters can be made out, appear to be just such forms as might be referred with about as much propriety to the Tertiary as to the Cretaceous. In fact, it is probable, from the general absence of characteristic Cretaceous types among them, (with the exceptions mentioned) that, if submitted to almost any paleontologist, not aware of the fact that the specimens of *Inoceramus* and *Anchura?* occurred in the same beds, the whole would be unhesitatingly referred to the Tertiary. The presence of two or three species of *Inoceramus*, however, and one of *Anchura?*, both of which, I believe, are generally regarded as having become extinct at the close of the Cretaceous epoch, taken in connection with the fact that these fossils are all marine types, while we have, up to this time, no evidence of the existence of any strictly marine Tertiary deposits in this central region of the continent, would certainly favor the conclusion that these beds belong to the Cretaceous.

From all the facts now known, I can therefore scarcely doubt that you are right in referring these beds to the Cretaceous. Indeed I had arrived at the same conclusion in regard to this formation, in 1860, from examining

[1] As elsewhere stated, one oyster brought from this formation by Colonel Simpson seems to be the same as an Upper Missouri species.

some of the same fossils *(Cardium, Inoceramus,* and *Ostrea)*, brought from outcrops of this rock on Weber River, in Utah, by the expedition under the command of Captain (now Colonel) J. H. Simpson.[1] In 1861, I also described, in connection with Dr. Hayden, the same *Cardium,* and an oyster, found on Gros Ventres River, associated with one of the same species of *Inoceramus,* by Captain Reynolds, referring them provisionally to the Cretaceous.[2]

The entire absence, so far as yet known, among the molluscan remains of this formation, of any species of *Ammonites, Scaphites, Toxoceras, Hamites, Ptychoceras, Turrilites, Heteroceras,* or any of the various other types, (excepting *Inoceramus,* and perhaps *Anchura)* generally considered either characteristic of the Cretaceous, or, in part, of that and older secondary rocks, and unknown in the Tertiary, would seem to indicate, with the presence of the latter types, that these beds belong to one of the very latest members of the Cretaceous; or, in other words, that they were probably deposited when the physical conditions favorable to the existence of those forms of molluscan life, peculiarly characteristic of the Cretaceous period, were drawing to a close, or had in part ceased to exist.

*Collections from the Bear River Estuary Beds.*

No 1. OSTREA.
No. 2. CORBULA PYRIFORMIS, Meek.
No. 3. UNIO BELLIPLICATUS, Meek.
No. 4. TIARA HUMEROSA, Meek.

The above-mentioned fossils, and various others brought from this same estuary, or brackish-water formation of Utah, by Colonel Simpson's party, in 1860, are all, with perhaps one, or possibly two, exceptions, to be mentioned further on, distinct, not only specifically, but even generically, from those yet known from the whitish or yellowish, coal-bearing, marine sandstones, holding a lower position in the same region. Indeed, the whole group of molluscan remains now known from these estuary beds shows clearly that marked

[1] See a paper by Mr. Henry Engelmann and the writer, in Proceed. Acad. Nat. Sci., Philad., Ap., 1860, p. 126.

[2] Ib., December, 1861, p. 440 and 442.

physical changes had taken place here, or were taking place, at the time they were deposited, since these shells are all such forms as we could only expect to find mingled together in an estuary deposit; while those from the whitish sandstones beneath as clearly point to a marine origin. This strongly marked change in the fossils, observed in passing from the lower to the upper of these formations, and the close similarity of those from the latter to foreign lower Tertiary species and living forms, and the entire absence, so far as known, of any characteristic Cretaceous types in these upper beds, are the grounds on which Mr. Henry Engelmann and the writer referred them to the Tertiary, in 1860.

One species, in the collections from the older marine sandstone under investigation, agrees so closely with *Corbula pyriformis*, from the estuary beds of Bear River, that I am strongly inclined to believe it belongs to the same species. The specimens in the sandstone are all merely casts, but they certainly agree in size and form with those from the brackish-water beds. The oyster, No. 1 of the above list, also seems to be the same as No 1 of the list of Chalk Creek species, two miles above Coalville, and No. 13, from Coalville; though I am not sure that the specimens from Bear River of this oyster were found *directly* associated with the estuary fossils, especially as the marine sandstones also occur there.

On comparing these collections with the fossils described in the California Reports, I observe that a shell, figured by Mr. Gabb, under the name *Corbula hornii*, from the very latest beds, referred by Professor Whitney to the Upper Cretaceous in California, is very similar to the Utah species, *Corbula pyriformis.* Indeed, I find nothing either in the figure, or in the description, of the California shell to distinguish it from the Utah species, or rather from a variety of the latter, with more regular and stronger marked lines and furrows, to which I had applied the name *C. concentrica*, but which I have since found to be only a variety of *C. pyriformis.* The oyster mentioned above as being apparently common to the estuary and marine beds seems to be also closely allied to *O. Idriamsis*, described by Mr. Gabb, from the highest of the California rocks referred to the Cretaceous. Oysters, however, often so nearly resemble each other, from rocks of different ages, that not much stress can be laid upon this apparent identity.

The above-mentioned facts, and the general conformability of these estuary beds to the marine sandstones of that region, referred to the Cretaceous, and their apparent unconformability to later deposits in the same country referred to the Tertiary, may suggest the inquiry whether we ought not to carry up the line between the Cretaceous and Tertiary here, so as to include these estuary beds also in the Cretaceous. This view would certainly seem to receive some support, from the fact that there is a formation on the Upper Missouri, near the mouth of Judith River, the exact age of which has long been regarded as somewhat doubtful, though Dr. Hayden and the writer have generally placed it in the Tertiary, that contains an exactly similar brackish-water group of fossils, some of which are identical with those found in these Bear River estuary beds; while some Saurian remains, discovered by Dr. Hayden at the Judith River localities, and at least *supposed* to be from the brackish-water beds, are regarded by Professor Leidy as being most nearly allied to Wealden forms.

The strata of the Judith River locality are upheaved and confusedly mingled together, and I have always thought that the Saurian remains found there may belong properly to undoubted Cretaceous strata that exist there beneath the estuary beds, rather than to the latter.

In studying Colonel Simpson's collections from the Bear River region, in 1860, I also identified an oyster from the marine coal-bearing sandstones there, referred to the Cretaceous, and holding a position directly beneath the estuary beds, with *O. glabra*, M. & H. brought in, enveloped in an exactly similar matrix, from near the mouth of Judith River, and stated that the last-mentioned specimens, also, probably came from the Cretaceous. Mr. Pope likewise informed me that some Saurian remains, found by Dr. Hayden on the upper branches of Moreau River, in Dakota Territory, and supposed to be associated with some Corbiculas, and one or two other brackish-water shells, are Cretaceous types.

Supposing the estuary deposits, at all of these widely-separated localities, to belong to the very highest beds of the Cretaceous, (the fact that they certainly hold a position above beds clearly equivalent to the latest chalk, if not even to the Maestrich beds, would preclude the supposition that they could belong to the horizon of the Wealden) we might readily understand

why they would contain none of the mollusks, usually regarded as characteristic of the Cretaceous, since the latter are, almost without exception, marine forms, while these beds were evidently deposited in brackish waters. Still, this would not account for the fact that among a considerable number of specimens, found ranging through some hundreds of feet of the marine sandstones, immediately below the brackish-water beds of Utah, strictly Cretaceous, or older types, are only known to be represented by the genus *Inoceramus* and possibly *Anchura*. Again, most of the mollusks yet known, from these brackish-water beds, at the several widely separated (and some intermediate) localities, seem to be nearly all either very closely allied to species found at the base of the Eocene, or lower lignite beds of France, or to existing East Indian or Chinese species.[1] Several of the species of *Vivipara*, found in the Judith River estuary beds, are exceedingly like existing East Indian and Chinese species, while some of these, and one or two of *Melantho*, as well as other associated forms, can scarcely be distinguished from species found in the higher fresh-water deposits of Dakota, acknowledged by all to be Tertiary, not only from position and from the affinities of their animal remains, but from the affinities of the numerous plants found in the same.

The probability is, that toward the close of the Cretaceous epoch, this region was gradually rising, and that portions of the Rocky Mountains, and other elevations farther west, existed as islands surrounded by the sea, and that as the gradual elevation of the continent continued, considerable areas that had been entirely occupied by the sea were more or less isolated, so as to become at first brackish and then fresh-water lakes. Whether or not this change from marine to estuary conditions was *exactly* contemporaneous with the close of the Cretaceous and the commencement of the Tertiary of Europe, we may perhaps never know, but that it corresponded in the

[1] It is a very interesting fact that we have from these brackish-water beds in Utah several of those subtrigonal corbiculas, very similar to *C. forbesii*, *C cuneiformis*, *C. antiqua*, and other forms scarcely distinguishable from species from the lower lignites of the Paris basin; and a *Tiara* equally as nearly allied to a form figured by Matheron from the same horizon at the mouth of the Rhone. The most remarkable fact in this connection is, that the genus *Tiara*, although represented by species now living in the East Indies, has no representatives among the existing fauna of America.

sequence of geological changes here with the change of physical conditions that closed the Cretaceous epoch and ushered in the Tertiary of Europe, especially in France, seems to me scarcely to admit of any well-grounded doubts. While I am, therefore, willing to admit that facts may yet be discovered that will warrant the conclusion that some of these estuary beds, so widely distributed here, should be included rather in the Cretaceous than in the Tertiary, it seems to me that such evidence must either come from included *vertebrate* remains, or from further discoveries respecting the stratigraphical position of these beds with relation to other established horizons, since all the molluscan remains yet known from them (my own opinions are entirely based on the latter) seem to point to a later origin.

Very respectfully, yours,

F. B. MEEK.

Having thus generally sketched the geological relations of the coal series where within the limits of this exploration they have been developed, it only remains to add some notes on the coal-mining district and upon the chemical and calorific nature of the coal itself.

Although coal has been known in this region since the early explorations of the Engineer Corps, it is only within six or eight years that mining has actually been prosecuted, and had it not been for the sudden demand for railroad fuel, the coal would have lain unutilized for an indefinite period. Under the stimulus of the railroad completion a number of important mines have been opened.

The coal series occupies a very wide geographical extent, reaching from New Mexico certainly as far north as Dakota, and in all probability stretching northward into British America. Its western boundary is the Wahsatch Range, from whose meridian it continues eastward as far as Central Colorado.

To the Green River Basin only have the observations of this Exploration been confined. So far no beds have been worked within this area except in the neighborhood of the Union Pacific railroad.

The valleys of the Weber, Bear, and Bitter Creek have been eroded through the overlying Tertiaries and opened up the coal series, and it is in their cañons that the main mining localities are found.

THE COALVILLE DISTRICT.—The Mormon settlement of Coalville is situated about five miles southeast from Echo City. From the mouth of Echo Cañon the road follows up the east bank of the Weber River, which, for the first mile and a half, occupies a broad, level bottom, eroded through the strata of Tertiary sandstones and conglomerates. The high red and brown bluffs which flank the river on either side, are very conspicuous features of the landscape. Continuing southward, the valley widens to the average breadth of a mile, and the upturned rocks of the coal series are seen rising on either side of the river, underlying with a nonconformity of 11° the red hills of the Tertiary. From this point for 16 miles the coal rocks are exposed on either side of the Weber River, rising into the hills to a varying altitude, rarely exceeding a thousand feet, where they lose themselves again beneath the Tertiaries, which continue upward two or three thousand feet higher. In other words, the river has carved a cañon, first, through the level Tertiary beds, and last, for a thousand to fifteen hundred feet into the soft, upturned strata of the coal series. By referring to the map, Atlas-Plate I, the Pacific railroad will be seen following Echo Cañon in a direction about northeast. Two miles to the south of that, a cañon is seen to cut the Tertiary strata parallel with Echo, joining the Weber River half-way between Echo City and Coalville. At the town of Coalville a third southwest stream joins the Weber. All three of these parallel systems have eroded the Tertiary and entered the coal series. Chalk Creek, as it is called, which enters the river directly at Coalville, has exposed the coal series for 18 miles, and in the tributaries which have worn ravines upon its northern bank are located the groups of mines embraced in what is known as the Coalville District. Directly south of the town, and in the right-angle formed by Chalk Creek and the Weber River, is situated Sprague's mine. The vein of coal outcropped indistinctly upon the level flat and has been followed by a couple of tunnels southward under a little rise of ground. In close conformity with the rocks of the region the strike is north 28° east, magnetic. The strata have a westerly dip of about 14°. The vein itself has an average width of 11 to 14 feet, resting directly upon the cream-colored sandstone and roofed by thin strata of the same material, which, passing upward, alternate with bands of shale and sand. A slight bending has taken place near the outcrop

of the vein, but after passing downward for a hundred feet the planes continue on with the utmost regularity. The coal itself is of a black, brilliant surface, with the same tendency to rectangular cleavage which is characteristic of all the western lignites. On the whole, there is an increasing tendency to solid masses as the bed descends.

In all the minor fractures of the coal may be seen thin flakes of a yellowish-white mineral which proves to be chiefly sulphate of lime. This mine, as it descends, will eventually pass under the Weber River, and it is to be feared that fissures in the overlying rocks will admit sufficient water to render mining difficult. The mine is already overburdened with water even at the shallow depth of fifty feet, which marks their lowest works.

Following the strike of this bed in a northeasterly direction after crossing the Chalk Creek, the Allen claim is found at a distance of about half a mile in the ravine northeast of Coalville. The land having risen from the bed of Chalk Creek to a height of perhaps 75 or 80 feet, the vein, which outcrops upon the surface in the form of an earthy-brown mass, is attacked by a tunnel driven northward 450 feet upon the strike. At the end of this tunnel several branch explorations have been run for short distances to the right and left, developing the vein with about the same conditions of width and solidity as in the Sprague's claim. At the extremity of the east drift the bed is cut off by the vertical fault which is also seen upon the surface of the ground, and, if the exterior indications are good for anything, the bed may be found again by a short winze sunk to the southeast. There is no noticeable difference between the coal of these two mines. Their amount of fixed carbon, volatile matter, and ash are almost identical. No attempt has been made to explore in depth, the owners being content to take out a few tons at a time in a very rude, uneconomic manner.

Two miles above Coalville, in a ravine which also enters Chalk Creek Valley from the north, is a group of four claims. The first of these is the Wahsatch Company's ground, lying upon the northwest side of the ravine, which here has a northeast direction. The strike of the rocks and the included bed of coal is north 45° east, magnetic, with a dip of 8° to the northwest. One hundred yards above, on the right-hand side of the ravine, is the Robertson claim, which, at the time of the writer's visit, was closed,

and a short distance still further up the ravine are two mines which occupy opposite sides of the creek. That on the left is the Chrisman; that on the right is the Johnson. The two right-hand claims, belonging to Robertson and Johnson, have but a small area of coal. The ravine marking their northwest limits, and a sharp eroded bluff 500 or 600 feet to the southeast, limit them in that direction. The Chrisman claim occupies an entire section and is of very great value, since its downward continuance is of indefinite extent. The lower opening of their claim is a tunnel going in upon the strike of the vein about 150 yards, communicating with an air-shaft and securing ventilation from above.

The vein, as developed by this tunnel, has an average width of 13 feet, and the coal appears to be of a denser, more coherent variety than the mines nearer Coalville. The same company has attacked the vein about a hundred yards up the ravine by sinking an incline on the dip of the bed about 300 feet. The vein, as exposed here, does not differ in any important respect from the other openings. From the position and character of the bed and its relation to the strike, it seems absolutely certain that this vein is the same one which is found in the Allen and Sprague's. It shows a remarkable conformity in dip and strike, an almost unvarying thickness, and a great persistence in all the characteristics of the coal.

The method and scale of opening of this little group of mines is hardly worthy the name of engineering; it is more properly a rough system of prospecting by which simply the existence and mode of occurrence of the beds has been demonstrated. It is utterly inadequate to all large yield and radically faulty in method. That the deposit is comparatively uniform, widely extended, and of very great value, there is no doubt, and careful modes of engineering will make this locality one of the most important and productive near the line of the Pacific railroad. The Mormon people have already connected Coalville with Echo City by railroad, and might, in a very short time, compete favorably with any other district in supplying the railroad system west of this point.

In Grass Creek Cañon, the next valley north of Chalk Creek, there are some half-developed coal claims, prominent among which is the "Church mine;" not enough work, however, is yet done to demonstrate their value.

Near Upton, a small settlement about eight miles up the Chalk, are further discoveries of coal, but, like those of Grass Creek, they are as yet only prospecting enterprises.

The same may be said of those promising beds developed along the Weber from Wanship to Kansas.

Passing east from Bear River City the coal series is not seen again until upon the east side of Green River, where for a hundred miles it reappears along the cañon-like valley of the Bitter Creek. Here the first mine is opened at Rock Springs, 124 miles east of Evanston. Following the road eastward are the following localities: Van Dyk mine, Point of Rocks, Hall mine, Separation, and Carbon. Of these we have only notes upon the Hall and Van Dyk, which are quoted, by permission, from the report of Messrs. Ashburner and Janin, mining engineers, San Francisco.

"The Hall Mine.—This property is situated immediately upon the line of the Union Pacific railroad, four miles west of the Black Buttes station, in Wyoming Territory. The claim, which was located by Mr. M. S. Hall, extends for two miles east and west, or along the line of the railroad, and back for a distance of six miles, toward the south, in the direction of the Black Buttes Mountains. How much or what proportion of this large tract is underlaid by the coal, it is impossible to state until more extensive explorations are made, or until the limits of the field are determined by boring. There is, however, no doubt that a very considerable area is covered by the two principal seams, and quite sufficient for the establishment of permanent works of exploitation. This mine was discovered in June, 1868, and work was commenced upon it in September of the same year. There are four seams of coal known to exist upon the claim. The upper one, 4 feet 8 inches in thickness, is near the surface, and has never been developed, as the coal would be likely to prove of inferior quality. The second seam is 5½ feet in thickness, and has been worked to considerable extent, furnishing all the coal that has been sent to market from this mine. The third seam, 12 feet below the second and separated from it by a stratum of shale, is 9 feet 8 inches in thickness, and promises to furnish a coal fully equal in quality to that taken from the one above. No work has been done upon it, further than to prove its existence. The lower seam is not developed, but sup-

posed to be about 3 feet in thickness. Samples were taken from the second and third seams, and the results, which coincide closely, are annexed herewith. The dip of the strata is toward the southeast, at an angle of 10° to 15°, which further work will determine accurately. So far the mine has been worked level free, and the main opening is 1,800 feet from the track of the Union Pacific railroad. The principal drift is 1,000 feet long, 6½ feet high, by 8 feet wide, and has been run in upon a very regular seam, the coal being of nearly uniform quality and appearance from top to bottom. The pillars left to support the roof are 10 feet square, and each room, of which there are now 28, is 160 feet long. When the mine was first examined, in August, no work had been done in it for three months, and every pillar was firm and solid, showing that the coal does not shake in the mine. Both the roof and the floor are of hard shale, very firm and unyielding, from which the coal cleaves without difficulty or waste. In mining there is remarkably little refuse, and so far everything taken from the mine has been regarded and accepted as merchantable coal. From the railroad to the mine the track is laid with heavy T-rail, which extends about 150 feet into the main drift; the remainder is laid with the same rail, weighing 25 pounds to the yard. The side track to the rooms in the mine have oak sleepers and pine ties, with flat rail.

Quality and Yield per Acre of this Coal.—The coal from both the second and third seams presents the same general appearance, though that from the third seam is reputed the best; but work enough has not been done to prove this statement. The analysis shows it to be very similar in quality even now, and more extensive mining may tend to produce a better coal than the number two seam furnishes. The specific gravity of each is 1.45; they are both of a lustrous, black color, and brilliant, conchoidal fracture; they do not soil the fingers, nor crumble into dust; they stand transportation remarkably well, and bear handling better than almost any coal we examined; they have a white, infusible ash, and no smell of sulphur was evolved during the analysis; they make about 52 per cent. of a dark-gray, friable coke. Mr. W. A. Wagner, who has been coal inspector for the Union Pacific Company, regards this coal as having but one superior (the Van Dyk), so far as his knowledge extends, along the line of the road, and his opinion is fully confirmed by the result of our own experiments. The engineers speak

highly of it, and their universal testimony was in its favor. The amount of clinker it makes is small, and the calorific effect for locomotives of one ton of coal was never stated as being less than equal to two cords of wood found in the Rocky Mountains, for railroad use. When we take into account the difference of bulk and ease of handling, the economical effect would be much greater.

One cubic foot of this coal weighs about 90 pounds; consequently the upper seam would yield, after deducting one-fifth for slack, waste, &c., about 8,000 tons, of 2,000 pounds, to the acre. The third seam will yield, on this same basis, 16,000 tons, or 24,000 tons in all. This deduction of one-fifth is liberal, and in excess of what may be reasonably anticipated; but, in absence of any experience longer than that of a few months, a large allowance should be made in order to cover possible contingencies.

THE VAN DYK MINE.—This mine is situated four miles east of Rock Springs, close by the railroad, some thirty miles west of the Hall mine. The seam dips into the hill at an angle of about 15°. There are three veins in all upon this claim, only the lower one being worked, which is 3 feet 10 inches to 4 feet in thickness. This seam had an excellent roof of shale and sandstone floor below, from which the coal cleaves freely. Above the vein is a thick covering of rock, extending to the top of the hill. The coal from this mine is considered, and is proved by analysis, to be the best hitherto found along the line of the railroad. It is of a lustrous, brilliant, black color, conchoidal fracture, and slacks less than any other coal that we examined; it will consequently bear transportation well. The calorific power of this coal is comparatively high, and its value for heating purposes would be represented by the number 113, the average value of all these coals being taken as 100. On this same basis Hall's upper seam would be represented by 95, and the lower seam by 90. This mine is now producing 50 tons daily, which is used on the engines of the Union Pacific railroad, and which is preferred to all other coals on the line of the road. It can be opened in a short time so as to furnish 150 tons daily, or more if desired. The chutes of this mine are directly over the road, and the coal is loaded into the cars or tenders at a cost, by contract, of $1 62, currency, which amount is increased by incidentals to $1 75 per ton. The seam of coal now worked is very compact, uniform in width, and remarkably clean, and free from any intermixture of slate. The yield per acre of this seam will be 6,000 tons."

*Table of Analyses and Values of Coals from Utah and Wyoming.*

| | Specific gravity. | Water. | Total volatile matter. | Fixed carbon. | Ash. | Litharge reduced by 1 of coal. | Carbon corresponding to volatile matter. | Total carbon. | Units of heat. | Color of ash. | Analyst. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sprague's, I | 1.325 | 1.68 | 47.27 | 48.78 | 3.95 | 23.50 | 20.44 | 69.12 | 5585 | Light reddish-gray | O. D. Allen. |
| Sprague's, II | 1.329 | 8.62 | 47.16 | 49.03 | 4.01 | 23.20 | 19.20 | 68.23 | 5513 | Light reddish-gray | Do. |
| Sprague's | 1.44 | . . | 54.00 | 42.53 | 3.47 | 20.46 | 17.64 | 60.17 | 4862 | White | Ashburner. |
| Wahsatch, lower tunnel | 1.311 | 8.38 | 47.06 | 49.68 | 2.26 | 29.90 | 26.49 | 76.17 | 6154 | Nearly white | O. D. Allen. |
| Wahsatch, upper tunnel | 1.303 | . . | 47.80 | 49.75 | 2.22 | 25.30 | 24.66 | 74.41 | 6012 | Nearly white | Do. |
| Wahsatch | 1.32 | . . | 50.00 | 46.73 | 3.27 | 20.79 | 14.42 | 61.15 | 4941 | Reddish white | Ashburner. |
| Johnson | 1.294 | 9.89 | 47.34 | 49.35 | 3.31 | 23.80 | 20.65 | 70.00 | 5656 | Light gray | O. D. Allen. |
| Robinson | 1.321 | 9.42 | 48.21 | 48.27 | 3.32 | 25.20 | 25.65 | 74.12 | 5989 | Light gray | Do. |
| Chrisman, lower tunnel, upper face | 1.324 | 10.33 | 49.28 | 47.83 | 2.89 | 24.00 | 22.76 | 70.59 | 5704 | Yellowish white | Do. |
| Chrisman, lower tunnel, lower face | 1.318 | 9.83 | 47.46 | 48.91 | 3.69 | 23.70 | 20.79 | 69.70 | 5632 | Yellowish white | Do. |
| Chrisman, upper tunnel | 1.319 | 9.56 | 48.09 | 48.14 | 3.77 | 23.80 | 21.86 | 70.00 | 5656 | Gray | Do. |
| Evanston, I | 1.341 | 8.07 | 43.06 | 47.34 | 9.60 | 23.70 | 22.36 | 69.70 | 5632 | Gray | Do. |
| Evanston, II | 1.346 | 8.10 | 42.70 | 47.67 | 9.67 | 23.70 | 22.03 | 69.70 | 5632 | Gray | Do. |
| Evanston | 1.33 | . . | 40.00 | 52.75 | 7.25 | 20.75 | 8.27 | 61.02 | 4930 | White | Ashburner. |
| Rock Spring | 1.35 | . . | 46.00 | 44.98 | 9.02 | 22.41 | 20.93 | 65.91 | 5325 | White | Do. |
| Hall's lower seam | 1.45 | . . | 48.00 | 48.02 | 3.98 | 18.45 | 6.26 | 54.28 | 4386 | White | Do. |
| Hall's upper seam | 1.45 | . . | 46.00 | 50.60 | 3.40 | 19.43 | 6.55 | 57.15 | 4618 | White | Do. |
| Point of Rocks | 1.34 | . . | 50.00 | 46.50 | 3.50 | 19.64 | 11.27 | 57.77 | 4668 | White | Do. |
| Van Dyk's | 1.28 | . . | 46.00 | 52.67 | 1.33 | 23.35 | 16.01 | 68.68 | 5549 | Brick red | Do. |
| Black Butte | 1.31 | . . | 46.00 | 50.78 | 3.22 | 19.99 | 8.02 | 58.80 | 4751 | Fuses into globules | Do. |
| Separation | 1.34 | . . | 48.00 | 50.57 | 1.43 | 20.62 | 10.08 | 60.65 | 4900 | Deep red | Do. |
| Total | 28.141 | 83.88 | 989.43 | 1020.88 | 87.56 | 475.69 | 366.34 | 1387.32 | 1120.95 | | |
| Average | 1.340 | 8.388 | 47.116 | 48.61 | 4.17 | 22.65 | 17.44 | 66.06 | 5338 | | |

# CHAPTER VIII.

## COLORADO.

GENERAL FEATURES—AGRICULTURE—MINERAL WEALTH—COAL AND IRON—PRECIOUS METALS—BULLION PRODUCT.

Colorado possesses a mineral wealth of varied character. Chiefly productive, thus far, of gold and silver, it has, in association with these metals, some valuable sources of lead and copper. Its coal beds are unquestionably of great extent, and, although as yet but slightly developed, they bid fair to become the basis of a most important branch of mining industry. Its deposits of iron ore are wide spread, and are said by intelligent observers to have great worth; while salt, gypsum, fireclay, and other mineral products of commercial value, occur and are already being utilized in several localities, forming noteworthy elements in the natural resources of the Territory.

It will not be attempted, in this or following chapters of the present volume, to describe minutely either the mode of occurrence of all these various mineral deposits or the manner or extent of their development. The writer's observation was confined almost exclusively to the examination of the principal gold-producing district of the Territory, situated in Gilpin County, and of the silver mining region of Clear Creek County, having in view the purpose of combining with the foregoing description of the gold and silver mining industry of Nevada, or of that part of Nevada which lies within the limits of the Survey, some account of the general condition of the same branches of industry in Colorado. Except in this special department of examination, the field operations of the Survey have not, at the present time, been extended eastward beyond Fort Bridger, and the writer, therefore, pursued his investigations without the co-operation of any other member of the corps. For this reason the topographical and general geological features of the country received less attention than was given to them in the Nevada mining districts, described in the preceding chapters, and cannot, therefore,

be noticed with much detail in this volume. Before proceeding, however, to speak particularly of the gold and silver mining industry of Gilpin and Clear Creek counties, a minute description of which is the main object of these pages, a very brief general notice of the Territory and its mineral resources will be given, in order that the reader may better understand the relation which those parts just referred to bear to the whole.

General Features.—The Territory of Colorado is included between the 37th and 41st parallels of north latitude and the 102d and 109th degrees of longitude west from Greenwich. It is, therefore, nearly rectangular in form, having a length from east to west of about 376 miles, and a breadth from north to south of about 276 miles, containing a superficial area of 104,000 square miles. It is bounded on the north by the Territory of Wyoming and the State of Nebraska, on the east by Nebraska and Kansas, on the south by the Territory of New Mexico, and on the west by that of Utah. It occupies the geographical center of that part of the domain of the United States which lies west of the Mississippi River; and its eastern boundary is 330 miles west of the meridian of Omaha, on the Missouri River. Denver, its capital city and principal town, situated 85 miles south of the northern boundary line of the Territory, is near the latitude of 39° 44′, and is about 25 miles south of the latitude of Philadelphia.

Its surface is advantageously and agreeably diversified by mountains and plains. The central portion of the Territory is traversed in a nearly north and south direction by the main range of the Rocky Mountains, whose crest line, at an altitude varying between 10,000 and 14,000 feet above the sea, divides the waters of the Atlantic from those of the Pacific. Eastward from the foot-hills of this main range, the surface of the country slopes off gently toward the Missouri River, forming a broad, rolling prairie, the average elevation of which, within the limits of the Territory, is between 4,000 and 5,000 feet above the sea. This wide expanse of level or gently undulating surface includes about two-fifths of the whole Territory, or 40,000 square miles, covering an area about as large as the State of Ohio. It embraces the valleys of the South Platte and the Arkansas Rivers. Some of the more favored portions lying along the tributaries of these streams are already under cultivation, producing excellent crops; and it is believed that

under the operation of practicable systems of irrigation the greater part of this entire region may be rendered available for agriculture.

The western half of the Territory is of more varied character. The face of the country, for the greater part, is very rugged and mountainous, but diversified by the great system of "parks," stretching from south to north along the mountain range, and affording within the elevated portion of the Territory large areas of land that are admirably adapted to cattle grazing and, probably, to some branches of agriculture.

The mountain sides are traversed by innumerable cañons, some of which are sharp and deeply cut ravines, while others expand, especially in the lower portions of the range, into broad, open valleys that abound in grass and timber. The streams, descending from the snowy summits of the mountains, are numerous and beautiful. They unite on the eastern slope to form the South Platte, the Arkansas, and the Rio Grande, while on the western side of the "divide," they find their way to the Colorado River and thus to the Pacific Ocean.

The climate of the Territory is temperate and healthy, and is agreeably varied by the different altitudes of mountains and plains. The atmosphere is dry and pure. The summer climate of the mountains is cool and bracing. Rain falls in frequent showers. In the winter the temperature is generally very moderate, and although the higher points in the range accumulate large bodies of snow, the less elevated portions, or at an altitude of 8,000 or 9,000 feet, are clear and pleasant, and the snow-fall is not sufficient to obstruct travel on the most frequented mountain roads. The climate of the plains is very even, without extreme heat in the summer or severe cold in winter. Snow seldom lies upon the plains in any considerable depth or for long periods of time, and cattle may remain out during the entire winter without protection, finding abundant grazing for their support.

The population of Colorado is very variously estimated, and is probably not far from 50,000. Immigration, however, is rapidly increasing as the facilities for access are constantly being multiplied. Until within a short period of time the region could only be reached by a long, tedious, and, oftentimes, hazardous journey across the plains; but since the completion of the Union Pacific railroad along its northern border it has been brought into

comparatively easy communication with the rest of the country, and the branch roads finished during the present year, 1870, now place Denver in uninterrupted railroad communication with two great transcontinental lines. At Cheyenne, which is 516 miles from Omaha on the Union Pacific road, the Denver Pacific road branches off to the south, and was completed to the city of Denver early in the present summer; while the Denver extension of the Kansas Pacific road was finished to the same point a few weeks later. With these two avenues of communication opened, one traversing the Territory north of Denver, skirting the mountain range, and affording cheap transportation for the mining as well as the agricultural districts, the other passing through the southeastern portion of the Territory, and bringing Denver into direct communication with St. Louis and the cities of the South, a great increase in the population of the Territory and an unprecedented advance in the development of its natural resources may be expected.

Denver, the capital city of Colorado, is located at the junction of Cherry Creek with the South Platte River, and a few miles above the point where Clear Creek unites with the last-named stream. It is twelve miles east of the base of the mountains, and is situated on a level or gently sloping surface. Its elevation above the sea is about 5,000 feet. It is regularly laid out and is well built, and some of its streets and public and private buildings make a fine appearance. Its population is usually estimated at 6,000 or 7,000. It has good hotels, several churches, excellent schools, and three or four newspapers, daily and weekly. There are also several banks and a Branch Mint of the United States. It is the commercial center of the Territory. It has abundant facilities for postal and telegraphic communication with the rest of the world. The railroads just completed bring it now within the great railway system of the United States; and daily lines of coaches connect it with the outlying communities of the agricultural districts and the several mining towns in the mountains.

Twelve miles west from Denver is Golden City, situated just at the base of the range where Clear Creek issues from its mountain valley. The main roads entering the mountains from the plains pass through this town. It is very advantageously located for commercial and industrial purposes. Placed at the very gateway through which the mining districts, at present

the most developed in the Territory, must be reached, and connected, as it soon will be, with the great railway lines of the West, it bids fair to rival Denver in the importance of its business relations with the mountain towns; while its abundant water power, its proximity to the coal mines, and their associated beds of iron ore and fire-clay, and its facilities for communication with the surrounding agricultural districts, combine to make it an important point for manufacturing and industrial pursuits. There are already extensive brick and pottery works established here, producing ordinary building brick and fire-brick of good quality, besides all kinds of common pottery for domestic purposes; three or four flour mills, one paper mill, a foundery, and several other manufacturing establishments. There are churches, schools, and newspapers, and a population estimated at 1,200 to 1,500.

Besides these more important cities on the plains there are several other smaller towns and villages, scattered through the agricultural regions or located in the neighborhood of the coal mines, that are steadily increasing in importance as the country is developed. Such are: Burlington, situated on the main stage road between Cheyenne and Denver, and in the midst of a well-cultivated farming country; Boulder, at the mouth of the cañon whence Boulder Creek emerges from the mountains upon the plains; Valmont, at the junction of the north and south branches of the same creek; Mount Vernon, a few miles south of Golden City, and several others, as Colorado City and Cañon City in the southern portion of the Territory.

The principal mountain towns are Black Hawk, Central City, and Nevada, on the head-waters of North Clear Creek, in Gilpin County, the center of the gold mining industry; Georgetown, in Clear Creek County, on the head-waters of South Clear Creek, and the most active point in silver mining; besides which are several smaller towns and villages, such as Idaho, Fall River, Empire City and others, that are located in the outlying mining districts.

The first three of the above-named towns, though possessing separate organizations, are, in fact, one settlement, being located in close proximity to each other. Black Hawk is situated at the junction of North Clear Creek with its tributaries, Chase Gulch and Gregory Gulch; Central City, a mile further up the stream, is at the point where Spring, Nevada, and Eureka

Gulches join Gregory Gulch; while Nevada is in the gulch of the same name, about a mile beyond Central. They thus form one continuous town, about three miles in length, and contain together about 6,000 people. They are connected with Denver and Golden City by daily stages and are about 40 and 28 miles distant from those places respectively, according to the length of the traveled roads. They are also connected by good mountain roads with the towns of neighboring districts. They are surrounded by mines, mills, and metallurgical establishments that will receive more minute description in the following chapter.

AGRICULTURE.—It will be seen that the natural wealth of the Territory is based not only upon varied mineral but also large agricultural resources. The latter at first attracted but little attention in a country that was chiefly opened by mining enterprise, but during late years, as the growing settlements created a permanent market for the products of the soil, the farming interests have greatly increased in importance, and during the past two years the reported value of the crops is but little, if anything, less than the bullion product.

Thus in 1868, according to Mr. W. R. Thomas of the Denver News, the agricultural statistics were as follows: Number of acres of land cultivated in wheat, 7,410, producing an average of 28 bushels per acre; acres cultivated in corn, 10,834, producing an average of 25 bushels per acre; acres cultivated in oats and barley, 3,709, producing an average of 35 bushels per acre; acres cultivated in potatoes, 1,966, producing an average of 100 bushels per acre. Estimated value of these crops, $2,683,840.

The crop of 1869, according to Mr. Cyrus Thomas, attached to Dr. Hayden's Geological Survey of Colorado and New Mexico, is larger than that of any preceding year, and is thus estimated: Wheat, 675,000 bushels; corn, 600,000 bushels; oats and barley, (nine-tenths oats,) 550,000 bushels; potatoes and other vegetables, 350,000 bushels; the market value of which, with that of the hay and dairy product, is placed at not less than $3,500,000.

MINERAL WEALTH.—The mineral products of commercial value are widely distributed throughout the Territory. The eastern base of the mountain range is flanked by the coal beds, which crop out, at frequent intervals, in the upturned strata of the foot-hills, and, extending thence east-

ward, underlie the plains to an unknown but doubtless very great extent. With these are associated the beds of iron ore and fire-clay, while the elevated portion of the range is traversed from north to south by the mineral belt, or system of lodes, in which occur the precious metals, gold and silver, in combination with lead and copper.

Coal and Iron.—The coal and iron deposits of the Territory have been studied with much attention by Dr. F. V. Hayden, United States Geologist, in charge of the Geological Survey of Colorado and New Mexico, who has published some of the results of his investigations in Silliman's Journal of March, 1868, and in his Preliminary Field Report, presented to the Secretary of the Interior in 1869. According to this observer, these beds are of Tertiary age. The coal is a lignite of very superior quality. The beds are exposed in many localities all along the eastern base of the mountains, not only in Colorado but in the neighboring Territories, the area covered by them, north of the Arkansas River, being estimated at 5,000 square miles. For a minute description of the geological features of this formation the reader may be referred to Dr. Hayden's official report, from which is taken the following section, showing the series of beds at Marshall's coal mine, 5 miles south of Boulder City and 17 miles north of Golden City, where the largest developments of the Tertiary coal-bearing strata are revealed:

48. Drab clay, with iron ore along the top of the ridge.
47. Sandstone.
46. Drab clay and iron ore.
45. Coal (No. 11), undeveloped.
44. Drab clay.
43. Sandstone, 15 to 20 feet thick.
42. Drab clay and iron ore.
41. Coal (No. 10), undeveloped.
40. Yellowish-drab clay, 4 feet.
39. Sandstone, 20 feet.
38. Drab clay, full of the finest quality of iron ore, 15 feet.
37. Thin layer of sandstone.
36. Coal (No. 9), nearly vertical, 12 feet.
35. Arenaceous clay, 2 feet.

34. Drab clay, 3 feet.

33. Sandstone, 5 feet; heavy seam of iron ore; drab clay, 3 feet; sandstone, 5 feet.

32. Coal (No. 8), 4 feet.

31. Drab clay.

30. Sandstone, 25 to 40 feet.

29. Drab clay, 6 feet.

28. Coal (No. 7), 6 feet.

27. Drab clay, 5 feet.

Dip 37°.
26. Sandstone, with seam of clay 12 to 18 inches, intercalated 25 feet.
25. Drab clay, 4 feet.
24. Coal (No. 6), in two seams, $4\frac{1}{2}$.
23. Drab clay, 3 to 4 feet.

22. Yellowish, fine-grained sandstone in thin, loose layers, with plants, 5 to 10 feet.

Dip 8°.
21. Drab clay, with excellent iron ore.
20. Coal (No. 5), 7 feet .............. 15 feet.
19. Drab clay ..........................

18. Sandstone, dipping 11°.

17. Drab clay.
16. Coal (No. 4). 20 feet; obscure.
15. Drab clay.

14. Sandstone, massive, 60 feet.

13. Drab clay.

12. Sandstone.

11. Drab clay.

10. Coal (No. 3).

9. Drab clay.

8. Sandstone.

7. Drab clay.

6. Coal (No. 2), 8 feet.

5. Drab clay.

4. Sandstone, about 25 feet.

3. Drab fire-clay, 4 feet.

2. Coal (No. 1), 11 to 14 feet.
1. Sandstone.

The same report presents the following analyses of samples of lignite from Marshall's mines that were submitted to Dr. Torrey by the Union Pacific Railroad Company:

| | I. | II. |
|---|---|---|
| Water, in a state of combination, or its elements, as in dry wood | 12.00 | 20.00 |
| Volatile matter, expelled at red heat, forming inflammable gases and vapors | 26.00 | 19.30 |
| Fixed carbon | 59.20 | 58.70 |
| Ash, consisting chiefly of oxide of iron, alumina, and little silica | 2.80 | 2.00 |
| | 100.00 | 100.00 |

The iron ore is mostly concretionary, but sometimes it is so continuous as to give the idea of a permanent bed. Much of it is full of impressions of leaves in fragments, stems, grass, &c. It occurs, throughout the intercalated beds of clay, in masses that vary from one ounce to several tons in weight, and is chiefly in the form of brown hematite. Selected specimens yield a high percentage in metallic iron.

The following is an analysis of a sample of the ore, made by Mr. Edward M. Kent, and quoted from a published report of the Belle Monte Furnace Iron and Coal Company:

| | |
|---|---|
| Iron | 41.3 |
| Oxygen | 17.7 |
| Gangue | 27.8 |
| Water | 12.4 |
| Loss | 0.8 |
| | 100.0 |

A blast-furnace was built by the company named above for the purpose of smelting iron, near the Marshall mines, which was in operation for two months, producing in that time 250 tons of pig iron. The result of this experience was that 5,000 pounds of ore yielded one ton of metal. In this

operation charcoal was used at the rate of 130 to 150 bushels per ton of iron produced. The supplies of wood in the neighboring foot-hills of the range are abundant. Charcoal costs, at the furnace, 16 cents per bushel; and the cost of producing metal, during the experimental work referred to, is stated at $45 per ton. The furnace has since been idle, the principal alleged reason being that the quantity of old iron in the country, consisting of useless machinery brought in early days from the East, is still so great as to supply the demand at a less price than the cost of manufacturing. The quality of this coal is superior to that of most lignites, and is pronounced by good judges quite equal, for ordinary purposes, to that of many of the Pennsylvania coals. For domestic use, steam generation, and other common uses of fuel it is excellent. Its adaptability to smelting has not yet been thoroughly tried. For use in a blast-furnace it probably has not sufficient strength to sustain a charge; and, so far as the writer is informed, it will not coke. By adopting furnaces constructed especially with a view to the employment of this fuel, it may be utilized for the smelting of gold, silver, lead, and copper ores, but this has not yet been attempted on any large scale.

The chief developments on these coal beds have been made at Marshall's mine, 17 miles north of Golden City; at Murphy's mine, 5 miles north of the same point, and several other localities along this section of the foot-hills. The extent of work performed has been limited by the demand, which thus far has been but little more than to supply Denver, Golden City, and other places in the immediate neighborhood with fuel for domestic purposes. This demand will doubtless greatly increase as soon as railway transportation is furnished between this district and larger markets. At Marshall's mine, when visited by the writer in 1868, there were but few men employed. The mine was opened by two tunnels, one about 200 feet, the other 450 feet in length, from which a number of diverging galleries and working chambers were opened, so that whenever necessary a large force of men could be employed in taking out coal. The coal seam is about 11 or 12 feet thick; it presents a beautifully clear surface, being mixed with very little shale or slate. The seam lies almost flat, dipping only about five degrees, and admirably situated for extensive and economical working. It is said that 20 men can break 100 tons of coal per day and deliver it at the mouth of the

tunnel. The demand, however, had not, thus far, called for that degree of activity. During the winter about 20 or 30 tons per day were mined. The price of mining, paid to the contractors, was $2 per ton, delivered in wagons at the mouth of the tunnel; and the price obtained from buyers was $4 per ton. The selling price in Denver, 24 miles distant, at that time, was from $10 to $12 per ton.

At Murphy's mine, 5 miles from Golden City and 12 miles from Denver, the seam worked is 16 feet thick, and, where opened, is upturned so as to stand vertically. It is opened, where cut through by Ralston Creek, by tunnels, the coal being broken down from above the level of the tunnel. The coal is of excellent quality. A force of about 18 men was employed, producing about 35 or 40 tons per day. The cost of mining, that is, the contract price paid to miners, was $1 50 per ton. Denver furnishes, thus far, the principal market for the coal of this mine.

Precious Metals.—The metal-bearing veins occur in the more elevated portion of the mountains, and form, at those points where developed in Colorado, parts of a great system, which is generally known as the Mineral Belt. This belt, stretching along the range from south to north, has only been explored at intervals; but, although broken here and there by unproductive regions, is probably, in a general sense, continuous for many hundreds of miles. Its limits are unknown, but it probably traverses the domain of the United States and, extending far beyond our boundaries, contains many new fields of mineral wealth that are still to be discovered and developed.

Superficial examinations and prospecting have been carried on over a considerable portion of its extent in Colorado, but persistent exploration, with a view to the development of mines, has thus far been confined to a few points. The mining regions thus opened extend from the central part of Boulder County in a southerly, or south-southwesterly, direction through Gilpin, Clear Creek, Summit, and Park Counties, forming a belt of ill-defined limits, but, so far as at present developed, from five to ten miles wide and from seventy-five to one hundred miles long. At many points along this belt metalliferous veins have been found, occurring in groups that are separated from each other by intervening barren regions. These veins are generally inclosed in granitic and gneissic or schistose rocks of metamorphic character.

They present the characteristic features of true fissure veins and many of them are rich in gold, silver, copper, and lead.

The relative association and method of distribution of these metals are very interesting, and although the subject has, thus far, been too little studied to afford data for much generalization, these lodes will, in future, furnish an instructive field for the student of vein phenomena. The gold-bearing veins of Colorado differ in many respects from those of California. The latter have generally a gangue of clear white quartz carrying free gold, with a comparatively small proportion of iron pyrites; those of Colorado are usually filled with a gangue rock composed of quartz and feldspar, sometimes porphyritic in character, and associated with a seam of ore which consists chiefly of auriferous copper pyrites and iron pyrites. Very little of the gold is free in the quartz, but is mostly combined or intimately associated with the pyrites; and, according to general observation, the copper pyrites is a much richer gold ore than the iron pyrites. Nearly all the gold-bearing veins carry some silver. The proportion of this latter metal is variable, but is seldom less than one ounce of silver for each ounce of gold, and oftentimes very much more.

While the gold-bearing veins almost always, if not invariably, carry some silver, the richest silver-bearing veins, as, for instance, those about Georgetown, are usually wanting in gold. The ores of these veins generally consist of argentiferous galena, mixed with comparatively little pyrites and enriched by the presence of true silver minerals in sulphureted and antimonial forms. In the several groups of veins one or the other of these types usually predominates. Those in the Gilpin County region, of which Central City is the center, the lodes are pre-eminently auriferous; although in the immediate vicinity there are veins that are strictly silver-bearing, and, so far as the writer is informed, entirely without gold; of such the Coaley lode, a half mile or a mile below Black Hawk is an example. Advancing in a southwesterly direction from Central City toward Georgetown, the gold veins become notably richer in silver, and, according to the observations of some, a gradually increasing proportion of silver may be discerned, until, ariving at the Georgetown district, the veins become entirely argentiferous in character and are almost, if not quite, without perceptible traces of gold.

The relations of these veins to each other, as regards their position, age,

structure, and contents, with a view to learn the causes that have produced their different characteristics have been but little studied and offer an inviting and interesting field for investigation.

It is now about eleven years since the first discovery of a gold-bearing lode in Colorado. The history of the finding of the precious metal, by pioneers, first in the streams emerging from the foot-hills of the mountains, then in the beds of creeks higher up in the range, and finally tracing it to one of the chief sources and revealing the place of the famous Gregory lode, has been sketched by Mr. O. J. Hollister, in his "Mines of Colorado."

As early as 1852 gold was discovered, by small traveling parties, in one of the streams which is a tributary of Clear Creek, near its junction with the South Platte, a few miles east of the base of the range. In 1857, gold, in considerable quantities, was obtained by prospectors in the neighborhood of Cherry Creek, and near the present site of the city of Denver. During the two succeeding years of 1858 and 1859, the streams of the foot-hills and, to some extent, the more elevated portion of the range, were visited by miners, who discovered some rich gold placers, and worked them with considerable success. On the 6th of May, 1859, after long and patient search, the discovery of what is now known as the Gregory lode was made by John H. Gregory; and this important event brought hundreds and thousands of men to engage in the search for the precious metal. The country was prospected far and wide. New and rich placers were opened and worked, lodes were discovered, mining districts were organized, and a great degree of activity in mining enterprise was developed, which prevailed during several years.

The history of the progress of these operations, during the ten years that followed the discovery of the Gregory lode, has become generally familiar, through books and public journals. It has been one of varied success and disappointment. During the earlier years, while the alluvial deposits of gold, along the bars and in the beds of streams, were yielding their rich stores without hinderance to the miner, and while the soft, decomposed surface ore of the mineral veins demanded but little skill and scarcely any machinery for the extraction of its valuable contents, the country was prosperous, and everything went well. When, however, the placers commenced to

show signs of exhaustion and the lodes, having been stripped of their easily-mined and readily-worked "top quartz," began to furnish ores that, although rich in gold, refused to yield it to the simple methods of extraction thus far in practice, a serious reaction ensued. The development of the lodes had already reached considerable depths and could no longer be worked without the investment of large sums of money in machinery for the extraction of rock and water. The character of the veins proved, also, to be quite variable, productive portions alternating with large masses of barren ground, requiring much unprofitable work in exploration, and oftentimes exhausting the patience and the means of the miner before affording any return. The ores, too, when obtained, were found to carry their gold and silver in such combinations that they could not be profitably worked without the introduction of metallurgical processes that were new to those who sought to use them, and that also demanded, for the provision of the necessary machinery, an amount of capital that was far beyond the power of the pioneers and settlers of the country to furnish. Companies were organized, and money was sought in the Eastern States for the development of the mines, and, for a time, the means were furnished freely by the capitalists of New York, Boston, Philadelphia, and other large cities. Unfortunately for the country the first result of these investments was a bitter disappointment. This was due partly to some gross misrepresentations, by means of which money was obtained, and partly to the ignorance and inexperience that caused much of it to be fruitlessly squandered. During the period of speculative excitement that prevailed in 1863, the most exaggerated statements were published concerning the resources of the new mining field, in order to induce the investment of capital, and estimates of the probable returns were made that would have been highly extravagant even if the statements on which they were based had been true. The supply of capital was, at first, abundant, but the men intrusted with the use of it were, for the greater part, novices both in mining and metallurgical matters, and the practical experience already gained in California and other portions of the United States seemed to avail but little in the new regions. The refractory ores offered serious obstacles to the profitable working of the mines, and as the inventive genius of the country was called upon to devise new methods of treatment, the place was soon overrun

by process-vendors, each of whom needed a considerable sum of money to put his newly-discovered process to the test. In some cases large and costly metallurgical establishments were built for the purpose of treating the ores of certain lodes before either the value of the lodes or the merit of the processes proposed had been ascertained. Large quantities of machinery were carried from eastern shops into the Territory, at extravagant costs for transportation, much of which, on arrival, was useless for any other practical purpose than to be broken up for old iron; and it is said that the supply of this material, from this source alone, has been great enough thus far to meet the demand of the shops and founderies of the mining regions. The natural consequence of the disappointment of so many vain hopes and of the utter waste of so much capital was a disastrous reaction, and, in 1864, the country, with its mining projects, fell into a state of disfavor among the monied men of the East, from which it has not yet wholly recovered, although the operations of the last two or three years have done much toward redeeming its character.

The present condition of mining industry in the Territory is more encouraging, probably, than it has been since the beginning of the depression which resulted from the failures of 1864; and although the annual production of bullion is less than the reported products of the earlier years, while the rich placers were being worked, the business, based as it is chiefly upon the development of mineral veins and only to a slight extent upon the readily exhaustible alluvial deposits, is assuming a more permanent and reliable form.

The years of 1865 and 1866 witnessed a period of inactivity, during which scarcely anything was accomplished in the development of mines or the production of bullion; but a few persistent parties persevered, and, in 1867, a revival of the business followed, which has since been steadily increasing in importance. Many of the large companies, formed in the days of speculative excitement, are still inactive, and some of the best lodes are standing idle, owing to various unfavorable conditions, some of which will be pointed out in the following chapter; but there are many smaller enterprises, owned and managed by individuals, who, although possessed of only a moderate capital, have been free from some of the evils of large corporations, and have accomplished success by conducting their affairs in a practi-

cal, business-like way, and in a manner adapted to the means at hand and the end in view.

The methods of mining are gradually improving; the costs of labor, materials and supplies are steadily being reduced; metallurgical processes adapted to the several classes of ore have been introduced into the region and successfully applied to their purpose, and the business is slowly but surely establishing itself on a permanent and healthy basis.

In the following chapters the principal gold and silver mining districts of the Territory, the first located in Gilpin County, the second in Clear Creek County, will be described, with the purpose of presenting the characteristic features of typical veins, the general method of their development, and the present condition of mining and milling industry. Besides the localities thus selected for description there are other outlying districts which formerly received much attention, and now, after a long period of inactivity, are again being worked. The mines of Boulder County, lying on the north of Gilpin, were wrought several years ago, with almost if not quite as much vigor as those of the last-named county. Several important mining districts were formed, many lodes were opened, and some of them acquired a great reputation. In the depression of mining interests, which came in 1864, this region suffered very much, and, during the writer's visit to the Territory, but little work was in progress. According to late newspaper reports, operations are being resumed. In Ward district alone there are five stamp mills, containing over 100 stamps, most of which are reported at work. The veins are productive both in silver and gold. The general type, however, appears to resemble those of Gilpin County.

Southwest from Central City, and between that point and Georgetown, there is a succession of mining districts, especially along South Clear Creek and its tributaries, which were once vigorously worked, then neglected, and are now again attracting renewed attention. There are many stamp mills and other establishments for the treatment of ores located along the course of the stream. Placer mining was formerly very productive on this creek, and is still a feature of some importance. Southwest of Georgetown, too, there is a good deal of activity along the mineral belt. The Snake River mines, in Summit County, and lying on the western slope of the range, are being

steadily developed, and will be briefly noticed in the final chapter; while beyond these are the districts of Park and Lake Counties, in which both placer and lode mining is in progress.

BULLION PRODUCT.—The bullion production of Colorado during the early years of its mining career cannot be accurately stated, as there are no complete records on the subject; and the statistics now in existence concerning a portion of the product afford but a narrow basis for a reliable estimate of the whole.

Mr. Hollister, in his "Mines of Colorado," furnishes a statement of the gold produced in the Territory, and deposited at the mint or its branches, from 1859 to June 30, 1866, amounting, in all, to $12,401,374 20. Assuming, then, that the deposits at the mints only embraced one-third of the total production of bullion—a rule which, as applied to the gold regions of Colorado, may well be questioned—he makes the bullion yield during that period $37,204,122 60. By others the product is variously estimated; some placing it higher than the figures given above, and some stating it at about $30,000,000.

The production of the past two years, 1868 and 1869, is estimated by the writer as stated below, on the following data: The greater portion of the bullion product is shipped to eastern markets by the producers and the purchasing bankers, through the office of Wells, Fargo & Co., in Denver. According to Mr. F. W. Jones, superintendent of that office, the average shipment thence per month, for the two years, amounts to $200,000, currency value—a little less in 1868 and a little more in 1869—not including those packages which are shipped *through* from Central City and Georgetown, without being rebilled in the Denver office. From data kindly furnished by the agents of Wells, Fargo & Co. at Central City, the writer estimates these *through* shipments from that point at $25,000 per month, currency value, in 1868, and $50,000 per month, currency value, in 1869. The bullion shipment of Georgetown, for the two years, may be stated at $300,000, coin value; a portion of which may have been rebilled at Denver, but, if so, will be partially offset by shipments of rich lead from Snake River and small parcels of ore, of which no other account can be taken. To these items are to be added from five to ten per cent. for undervaluation of bullion shipped, and an allowance for bullion carried out of the country by private hands, not exceed-

ing 20 per cent., according to the best informed. Further, the product of the Boston and Colorado Smelting Works (Professor Hill's), of which an estimate is given on a following page; and finally 100 tons of rich ore from the Equator and Terrible mines at Georgetown.

These items may be summed up as follows:

| | |
|---|---|
| Shipments from Denver office, 24 months, $200,000, currency, per month, $4,800,000, or coin | $3, 600, 000 |
| Through shipments, not included in foregoing, from Central City, 24 months, $900,000 currency, or, in coin | 675, 000 |
| Shipment of bullion from Georgetown, two years | 300, 000 |
| Allowance on above for undervaluation and for private hands | 1, 300, 000 |
| Boston and Colorado Smelting Works' product to January 1, 1870 | 570, 000 |
| 100 tons ore from Equator and Terrible mines | 55, 000 |
| | 6, 500, 000 |

Making a total, for the two years, of $6,500,000, coin value, something more than one-half of which is to be credited to 1869.


MAP OF THE
GILPIN COUNTY
GOLD REGION.
Colorado Territory
Central City
Winnebago
Gunnell
Gunnell Hill
Burroughs
California
Gardner
Illinois
Forks
Flack
Mercer Co.
Quartz Hill
Alps
Perrin
Consolidated Ditch
Gregory Hill
Bobtail
Mammoth Hill
Lake
Ditch
1000 500 0 1000 2000 3000 4000 5000 feet

# CHAPTER IX.

## GOLD MINING IN COLORADO.

SECTION I.—GILPIN COUNTY GOLD VEINS—BOBTAIL, GREGORY, BATES, ILLINOIS, GARDNER, BURROUGHS, FLACK, CALIFORNIA, WINNEBAGO.

SECTION II.—TREATMENT OF THE ORES—MILLING—SMELTING—BULLION PRODUCT OF GILPIN COUNTY.

This chapter will be devoted to a description of the present condition of mining industry in Gilpin County, where, as already shown, the principal gold-producing mines of Colorado are located.[1]

This county, the smallest in the Territory, lies on the eastern slope of the mountains, and covers the area of country that is drained by North Clear Creek and its tributaries. The accompanying map, on Plate XXIX, presents the main topographical features of the region referred to.[2] The extent of country indicated in this map is about six miles long, east and west, by about four miles wide, north and south.

Central City, located at the junction of Spring, Nevada, and Eureka gulches, is, as its name may imply, the center of mining activity. The most important and best developed lodes of the region are grouped about this point within a circle of two or three miles in diameter. A great number of veins have been discovered and prospected within this area, and some of them have been extensively developed, a fact clearly indicated by the many mining works

[1] The writer takes occasion here to express his acknowledgment to many gentlemen residing in the mining regions of Gilpin County for their courteous attention and aid in obtaining desired information; he is especially indebted to PROFESSOR N. P. HILL, Mr. H. B. BRASTOW, Mr. G. L. BRADLEY, Mr. A. VON SCHULTZ, Mr. J. ALDEN SMITH, Mr. JOSEPH THATCHER, and Mr. FRANK YOUNG.

[2] The map here given has been prepared chiefly from one made and published by Messrs. Morse and Hill, engineers residing at Central City; and from topographical details furnished to the writer by Mr. A. N. Rogers, an experienced topographer, superintendent of the Bobtail mine.

that crowd the surrounding hills. To describe all these lodes, and the mines opened upon them, would be impossible, within reasonable limits, and a mere enumeration of them would be useless. It may suffice, therefore, for the purposes of this chapter, to select typical veins for description, choosing those that have been most extensively worked, since they afford the largest opportunity for observation in depth and length, and, at the same time, furnish the most characteristic illustrations of the general method of development.

Concerning these lodes in general, it may be said that they are all inclosed in rock which is of one common type, chiefly granitic, with some gneissic varieties. They possess a high degree of parallelism in their strike or direction; their course, with few exceptions, being between due east and west on one hand, and northeast and southwest on the other. Within these limits the prevailing direction or course, among the prominent lodes, is nearly due east and west, or from 5° to 10° north of east. The Gregory, Bates, and a few others are exceptions to this statement, but the Bobtail, Burroughs, Gardner, Flack, Gunnell, Winnebago, and others, strike about north 85° east, and represent, more nearly than those before mentioned, the average course of veins in the district. The dip of the lodes is generally at a high angle, or nearly vertical. They possess the distinctive features of true fissure veins, and they are remarkably free from faulting or displacements.

In the following pages some of the most noteworthy lodes, which, in many respects, may serve as representatives of the others, will be described, with the view of presenting to the reader the characteristic features of the veins and the mode of occurrence of their ores; the manner in which the mines located upon them are developed, with some details concerning the cost of mining, the value and yield of the ores, and the relation of cost to production.

The latter part of the chapter will include a description of the principal methods of treating the ores, and some statistical information concerning the operations of stamping mills; the cost of milling and other metallurgical treatment; the relation of assay value to the yield of the ores, and a statement of the bullion production of the district.

BOBTAIL LODE.—The Bobtail lode has the reputation of having been the most productive vein of Colorado and of still producing the richest gold ores.

It crops out on the northern slope not far below the crest and several hundred feet above the base of Bobtail Hill. The hill itself is on the south side of Gregory Gulch, about half-way between Central City and Black Hawk. West of it is Gregory Hill, from which it is separated by a shallow ravine. The western limit of what is commonly known as the Bobtail lode is at or near this ravine, and is traced thence easterly about 800 feet along the steep side of the hill referred to.

This vein is one of a number closely related to each other, of which the relative positions are approximately indicated in the accompanying sketch on Plate XXIX. The prominent members of this system, if such it may be termed, are the Bobtail, Fiske, Gregory, and Bates, all of which, so far as yet appears, have convergent courses, so that, if continuous, they probably intersect or unite with the Mammoth lode, a large vein opened further west and traced for a distance of several thousand feet, coinciding closely in course, dip, and alignment with the Bobtail. This relation, though not clearly established by actual developments, seems very probable. The Bobtail is by many persons considered as a continuation of the Mammoth, faulted or somewhat displaced, perhaps a hundred feet, in the neighborhood of the ravine that separates Bobtail Hill from Gregory Hill. However this may be, there is a lack of visible continuity between the western portion of the Bobtail on the east side of the ravine and the distinctly recognized openings on the Mammoth on the western side of the ravine; so that, practically, the name of Bobtail only applies definitely to the lode east of the ravine.

The average course of the lode, for the length of 800 feet east of the ravine, is 75° east of magnetic north; or, allowing 15° for variation of the compass, is east and west, true. Its dip is almost vertical, varying a little in places, and sometimes inclined to the northward, sometimes to the southward. The width of the vein varies from a few inches, or a mere seam, to 10 or even 15 feet, but does not exceed 3 or 4 feet on an average.

The inclosing rock may be generally described as gneiss, though having sometimes a distinctly granitic character. It possesses the common characteristics of the, probably metamorphic, rock that prevails throughout the more elevated portion of the mountain range. It frequently shows a thinly-banded structure, the lines of banding or bedding dipping easterly. The walls of the

vein are usually pretty well defined, the south wall more especially so. This is almost always easily followed and presents the ordinary features of the wall of a true fissure vein. A thin clay selvage, or parting, between the wall and filling of the vein, is apparent in most places. The north wall seems to be less regular, and, in some parts, is difficult to distinguish. The filling of the vein is a quartzose and feldspathic mixture, highly siliceous, and carrying much free quartz, but not having the usual characteristic appearance of solid quartz veins. In many places even where the vein is wide and well-defined, the filling of the fissure has a granitic look, differing but little in appearance from the country-rock, and usually, in such cases, it is quite as barren. The gangue accompanying the ore is a soft, whitish, or pale-greenish rock, consisting chiefly of decomposed or altered feldspathic material, mixed with quartz, and thickly impregnated with iron and copper pyrites, usually in small crystals. The richer ore is concentrated in a seam of solid sulphurets, consisting mainly of iron and copper pyrites, intimately mingled with which are comparatively small quantities of galena, zincblende, arsenical pyrites, and other allied minerals. The precious metals, chiefly gold, but rarely, if ever, entirely without silver, are associated with the pyrites. Usually the fine copper pyrites is the richest source of gold; the iron pyrites, when fine and close-grained, is also a rich gold-bearing ore, but when coarse-grained and crystalline it is much lower in value.

The productive portions of the vein usually carry a seam of the solid, gold-bearing pyrites, varying in width from an inch or two to two or three feet. An average width of ten or twelve inches is deemed an excellent vein of pay-ore. This seam of pyrites is usually accompanied by a mass of vein-matter or gangue, from one to three or four feet in width, which carries the finely-crystallized sulphurets, generally disseminated through it, as already described. These two methods of occurrence of the ore furnish two qualities for treatment; the last named, that which fills the greater part of the vein, affording stamp-rock that yields about an ounce of retorted amalgam, or $16 50 to $18, coin, per ton; the former, or the concentrated seam of pyrites, affording the first-class or smelting ore, assaying from three to twelve, and averaging about six ounces of fine gold and six ounces of fine silver per ton, besides the copper, which, when saved in the smelting process, forms an important element of its value.

The distribution of ore in the vein is not uniform. Some portions of the ground, for considerable distances, both horizontally and vertically, are barren; the walls approach each other; the vein matter pinches out, or, sometimes, the vein, where preserving its width, is filled with barren rock. In some places the fissure is filled with a good vein of stamp-rock, with little or no first-class ore; in others the solid seams of sulphurets, the copper and iron pyrites, attain and preserve for considerable distances, a width of two feet or more. Commonly, however, as has just been stated, the vein, where productive, consists of a seam of gold-bearing pyrites, eight or twelve inches in width, with an accompanying belt of pay-ground, having the ore more or less liberally distributed through it, and affording stamp-rock of fair quality. The average yield of the stamp-rock of this lode is six or seven ounces of retorted amalgam per cord of ore. The ounce of amalgam is worth from \$16 50 to \$18, coin. The cord contains from seven to eight tons. The yield is accordingly about \$14 or \$16, coin, per ton.

As nearly as could be ascertained from the officers of the Bobtail mine, working on the western portion of the lode, the proportion of first-class ore to the second-class or stamp-rock, was about one-tenth; while the whole amount of ore of the two grades was estimated to be from one-third to one-half of all the rock raised from the mine.

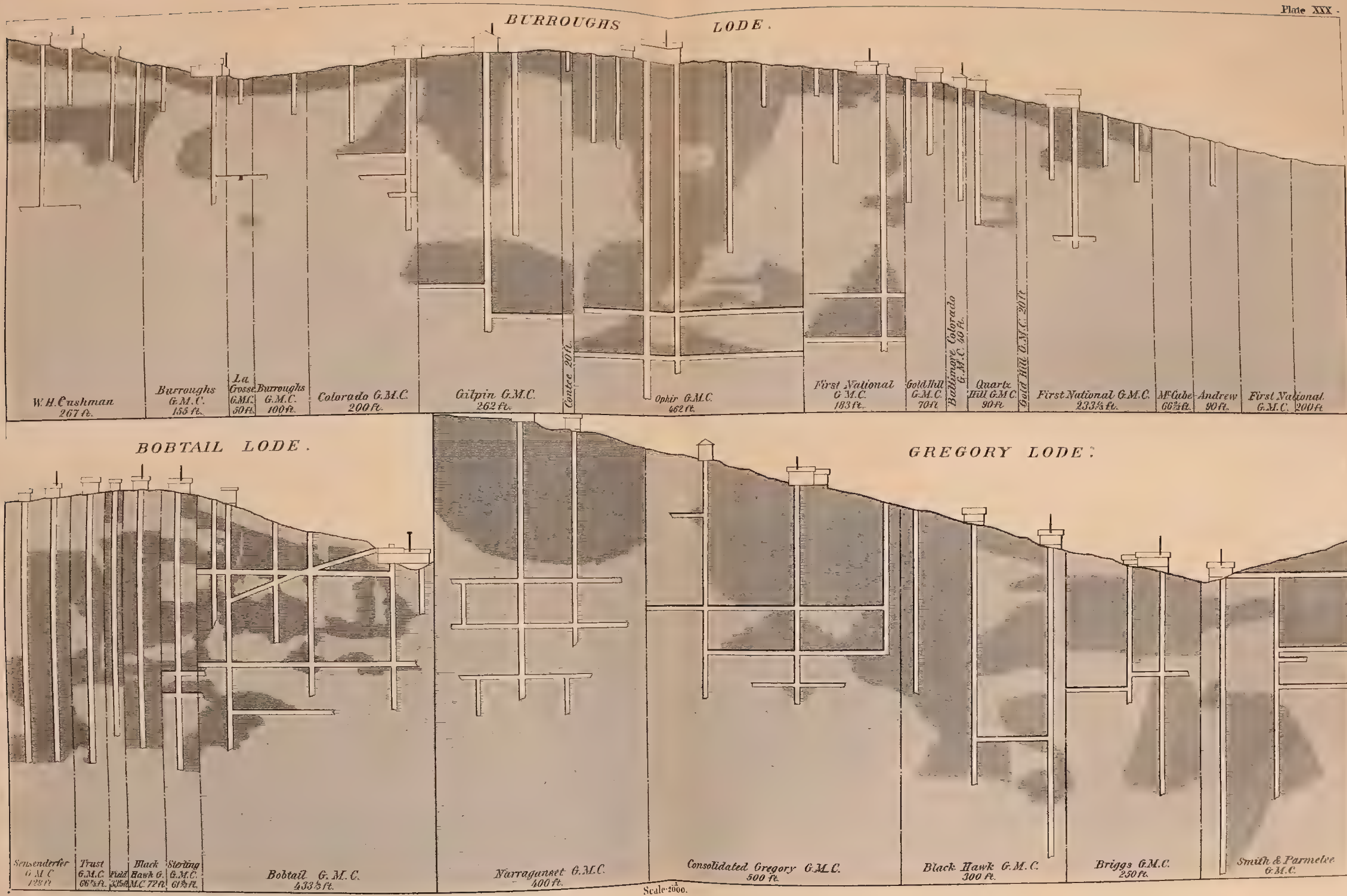
The lode is clearly traced and is developed for 800 feet in length. Unfortunately that extent of ground, itself not more than enough for one well-managed mine, is divided up into six independent claims, some of them very short, not only increasing greatly the costs of superintendence and general management, but presenting great hinderances to the economical opening and working of the ground. These claims, beginning at the west end in the ravine and proceeding easterly, are as follows:

| | Feet. |
|---|---|
| The Bobtail Gold Mining Company owning | 433⅓ |
| The Sterling Gold Mining Company owning | 66⅔ |
| The Black Hawk Gold Mining Company owning | 72 |
| The Field Gold Mining Company owning | 33⅓ |
| The Trust Gold Mining Company owning | 66⅔ |
| The Sensenderfer Gold Mining Company owning | 128 |
| | 800 |

On Plate XXX will be found a longitudinal section of the lode, showing the relations of these claims to each other, and something of the manner in which they have been worked. This section is prepared from one furnished to the writer by Mr. A. N. Rogers, superintendent of the Bobtail mine.

The development of these claims has reached an average depth of about 500 feet. They have been worked independently of each other, except in the matter of drainage, which has been effected by pumping machinery, owned and operated by the several parties on joint account. But the very limited extent of most of the claims has been the cause of very irregular work below ground, especially in those east of the Bobtail Company. Each claim, even the shortest, has carried on its operations through an independent shaft, usually stoping the ore underhand as fast as made accessible by the shaft. No systematic opening of the ground, in advance of the stopes, or economical or advantageous methods of attacking or handling the rock can be employed under such conditions. The vein is not wide, and the rock is hard, making the costs of sinking and stoping very considerable; water is abundant and its removal involves much expense; nor is the vein uniformly productive. All these qualities demand economy and a well-organized and comprehensive system of management as the first condition of permanent and successful mining. In the absence of this the profits are likely to be absorbed by the multiplied costs of administration when the lode is productive, and when the lode becomes poor, in any given portion, the work is liable to be abandoned by the parties that are most affected, and only resumed when the neighboring claims have afforded renewed encouragement.

The Bobtail lode has been remarkably productive, and has yielded very rich ores, so that, in spite of all the existing disadvantages, it has, during its history, paid large profits to its owners. Nevertheless, its operations of late have been less prosperous. Some of the shorter claims, under temporary discouragements, stopped work two or three years ago; the others, owing to various causes, of which the inefficiency of the pumping apparatus has been an important one, and the necessity of investing largely in machinery and other improvements another, have been unable, for some time, to make any dividends; and, in the summer of 1869, all work on the lode was suspended, awaiting the result of negotiations then in progress, having in view the consolidation of the various companies interested in the property.




Scale $\frac{1}{2000}$.

*Bobtail Mine.*—The first of the above-named companies, the "Bobtail," owns more than one-half of the developed portion of the lode, and is therefore able to carry on its operations more advantageously, in some respects, than the neighboring mines, that are much shorter in extent. The upper portion of the ground is said to have been worked in early days by various parties, who gouged out what they could without method or regard for the future, and although it yielded largely in rich ores, the present company, working the mine since 1864, have not only encountered a good deal of poor ground, but have been obliged to spend much money and patient effort in providing proper machinery and getting the mine into a suitable condition for economical operation. It was originally opened by several vertical shafts, two of which have been continued by the present company, and are now connected with an incline, through which all the ore is hoisted to the surface. The accompanying section indicates the general character and extent of the work. The hoisting machinery is at the west end of the property, from which point the incline starts and, going easterly in the plane of the vein, but descending at an angle of about 20°, connects first with the vertical shaft near the center of the mine, and afterward with the east shaft, about fifty feet from the east boundary line. A carriage, operated by the winding machinery at the surface, travels on a tramway in the incline, carrying the bucket, which latter, by an ingeniously-devised contrivance, is lowered into either vertical shaft on arrival at the point of junction of the shaft with the incline, and, on being hoisted, resumes its place on the carriage, and is thus taken to the surface. When connection with the east shaft is desired, the central shaft is covered by a bridge. The east shaft, which is the deepest on this mine, had reached a depth of 440 feet in the summer of 1868, and was then in progress of further sinking. The central shaft was between 300 and 400 feet deep. Further west, directly under the shaft-house, is another vertical shaft, not far from 400 feet deep, but which had been a long time unused, even previous to the suspension of other work, on account of excess of water. The vein, in this part of the mine, is said to be pinched, or, as locally termed, "in cap," and, at present, not very promising. It is not drained by the present pump-shaft, and as the water is too abundant to be removed by the means at hand the work of sinking was interrupted.

The eastern part of the ground is better than that further west, and has therefore been more extensively worked. When visited by the writer there was a good vein of smelting ore in this part of the mine, varying from 12 to 18 inches in width, accompanied by about 24 inches of fair milling ore. The upper part of the mine is pretty thoroughly worked out, but the deeper portion has been opened by levels, making the ground available for backstoping. As this had been done only to a limited extent the force that could be employed in producing ore was not large. During the season previous to closing the mine its average product was 240 or 250 tons of milling ore per month, yielding about $15, in coin, per ton, besides which, during the foregoing year, some 20 tons per month of first-class ore had been sold at the Smelting Works, at an average price of little less than $70 per ton, in currency.[1]

The hoisting machinery on this mine has been provided with a view to permanent work, and is very well adapted to its purpose. It is substantial and is compactly arranged, and but one or two other mines in the Territory are equally well equipped. It consists of two engines, each having a cylinder 10 inches in diameter by 20 inches stroke, geared together to drive a common shaft, by which the winding reels are set in motion. The reels are operated by friction-gear. The style of this hoisting machinery is generally similar to that in use at the North Star mine, on the Illinois lode, which will be described in more detail further on.

There are two spools, one of which is devoted to the incline, the other to the vertical shaft at the west end of the mine, near the engine-house, thus commanding three shafts.

The engines have greater power than is necessary for the work of the mine, and were provided with the view of furnishing power to a stamp mill to be built on the same premises. Steam is furnished by a single locomotive boiler of about 35 horse-power capacity, consuming two and a half cords of wood per day. The machinery is inclosed in a neat engine-house built of stone, with which is connected a spacious shaft-house, covering the ore-assorting floors, forge, and repair shops. The drainage of the whole lode is effected by the pumping apparatus on the adjoining claim.

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[1] The relation of the value of the ore to the price paid by the Smelting Works will be shown further on.

Since the present superintendent, Mr. A. N. Rogers, undertook the management of the affairs of this company in 1865, they have spent about $100,000 in improvements; their product in that time is not definitely known to the writer, but is considerably in excess of that sum. According to Mr. Rogers, the proceeds of the mine during the year previous to August, 1869, were some $25,000 or $30,000 in excess of the costs of working.

*Sterling Mine.*—Next east of the Bobtail Company's mine is that of the Sterling, owning 66⅔ feet. This claim is opened by a vertical shaft which has reached the greatest absolute depth of any on the lode, and is used by the Drainage Company as a pump-shaft. The mine has been worked out above, but, when seen by the writer, previous to the suspension of work, there was a very good vein in the bottom, carrying a seam of compact iron and copper pyrites, a foot or more in width, besides a belt of stamp-rock of good quality. The ores are essentially of the same character as those of the neighboring mine just described. During the year previous to closing the mine something over 150 tons of smelting ore had been sold at the Smelting Works, on which the mine realized about $90 per ton, in currency, its average tenor being about six ounces of fine gold and six or seven ounces of fine silver to the ton. The mine has good ground, but, as has been just observed, it is too short in extent to be worked advantageously. Its hoisting power is derived from the engine on the next claim on the east, the Black Hawk Company.

The pump of the Drainage Company, established in the Sterling shaft, consists of a 10-inch force-pump, or plunger, which is placed about 250 feet below the adit-level; this level, 130 feet below the mouth of the shaft, passes through the mine of the Bobtail Company, as may be seen in the section, and delivers the water in the ravine, west of the Bobtail works. Below the plunger-pump is a draw-lift of 12 inches diameter, raising the water from the bottom of the mine to the cistern supplying the force-pump. The column above the plunger is a 10-inch pipe, except where, for want of a sufficient supply of the latter, two 6-inch pipes are introduced as a substitute. The driving power, set up in the shaft-house at the surface, consists of an engine with a cylinder 14 inches in diameter and 30 inches stroke, geared directly to the shaft carrying the driving pinion, but, owing to several miscalculations, and partly to the lack of proper steam capacity in the boiler provided for the purpose, it

has not been made to work satisfactorily, and, under these circumstances, the pump was worked by the engine on the Black Hawk property, the power being transmitted by a line-shaft and thence by belting to the pump-gearing. These appliances are unsubstantial and ill-arranged for work so important as the drainage of the lode, which is very abundant in water, and the inefficiency of the apparatus has been the cause of great hinderance to the several mines dependent upon it, especially as most of them are almost as deep as the pump-shaft and are frequently obliged to suspend operations altogether on account of water. The pump, while running, worked on a six-foot stroke, making from seven to ten strokes per minute, and was obliged to run night and day steadily.

The Drainage Company is an association of the several working companies on the lode. The costs of operation are allotted among them according to the length of their claims, the pump-shaft being sunk by the Sterling Company, except under certain conditions, when the expense of sinking is partly borne by the association. But the number and diversity of interests of the several parties do not serve to promote good management, and their experience affords evidence of the disadvantage that arises from subdividing what might be one good mine, if conducted as a whole, into a half dozen independent and sometimes conflicting parts. The Drainage Company, since its organization, have expended over $100,000. The running expenses, when in operation, were about $1,600 per month.

An intimate connection between this lode and the neighboring lodes, the Fiske and Gregory, is said to be shown by the drainage; the last-named, when worked to a deeper level than the Bobtail, having drained the latter completely; while under reversed conditions, the Bobtail drained both the Fiske and Gregory. The Running lode, opened a half mile east of the mines on the Bobtail, and regarded by some as a continuation of the same, and by others as a separate lode,[1] is said likewise to be drained by the Bobtail pump. Nevertheless the west shaft of the Bobtail mine is filled with water some 40 or 50 feet above the bottom of the pump-shaft. With regard to this it is stated that the shaft was perfectly drained, until, in sinking, a large stream of

[1] The writer did not visit it.

water was cut, driving the men out and filling the shaft; and on being suffered to stand in that condition for a season, the crevices and clefts about the bottom of the shaft, formerly affording passage to the water, may have become choked with clay and thus impenetrable.

The next two claims on the east, the Black Hawk and the Field, have been worked to a depth of about 400 feet and have been very productive, especially, it is said, the latter.

*Trust.*—The Trust mine, claiming 66⅔ feet, next east of the Field, has been worked to a depth of about 540 feet or little more. Nearly all the productive ground has been worked out to within a few feet of the bottom, where the vein, at the depth just mentioned, was four or five feet wide, with two feet of pay-ground. The mine has a good shaft five feet by ten in the clear, divided into two compartments, one for hoisting and one for a ladder-road. It is well timbered with roughly framed sets, six feet apart, and lined up with three-inch plank. There are no hoisting works belonging to this company. Power is derived, by means of a line-shaft, from the neighboring mine. This claim has not been very productive of late, the shaft having been in poor ground. Some of the first-class ore, however, is of high grade; one lot of four or five tons, taken out at the time of the writer's visit, contained eleven ounces of fine gold and twelve ounces of fine silver to the ton. The average value of its ores is not essentially different from that produced by the other claims on the lode.

*Sensenderfer.*—The next claim, and the eastern limit of the developed portion of the lode, is the Sensenderfer. This mine has the enviable reputation of having not only the richest ore, but the most uniformly productive ground, of any of the claims on the vein. It is worked by means of two shafts to a depth of more than 500 feet, and although pretty much worked out above, the bottom of the mine, when work was suspended, showed a strong vein, two feet wide, filled with ore of high grade. During several years this claim was worked by Mr. John Sensenderfer, who is reputed to have taken from it a large amount of gold. It has also been idle for various reasons during much of the time since its first discovery. Since 1866 it has been worked by a company, consisting chiefly of a few gentlemen residing in Central City, and during that time has been one of the most profitable enterprises in the Territory.

The entire product of ore was usually sent to the stamping mill without selection of first-class for smelting, and yielded on the average fifteen ounces of gold to the cord of rock, or two ounces per ton. In some cases three or four ounces per ton were obtained.

Late in the summer of 1868 the company began to select the best of their ore for smelting in order to avoid the loss involved in treating ores of so high a value by the ordinary stamping process.

| | | |
|---|---|---|
| During the two years ending September 1, 1868, the total product[1] of this claim was, in currency | | $197, 155 |
| Of which the costs of production were— | | |
| For mining, 600 cords, say 4,500 to 4,800 tons | $51, 089 | |
| For milling, 600 cords, say 4,500 to 4,800 tons | 26, 846 | |
| | | 77, 935 |
| Leaving as profits, currency | | 119, 220 |

Out of these profits ten dividends of $10,000 each were paid previous to November, 1867; during the succeeding year no dividends were paid, as the mine not only required considerable outlay for improvements, but suffered much delay and embarrassment on account of water. In the summer of 1868, however, the work was going on profitably.

During the month of August of that year, which may serve as an average, the costs were stated about as follows:[1]

| | |
|---|---|
| Ordinary mining expenses, in currency | $2, 600 |
| Proportion of pumping costs | 800 |
| Hauling ore to mill, 30 cords, at $11 | 330 |
| Milling costs | 700 |
| | 4, 430 |

Costs, per cord, $147 66, or about $18 50 per ton of ore, in currency. Of the above quantity of ore the yield at the usual average rate of 15 ounces

[1] From statements furnished to the writer by Mr. George T. Clark, treasurer.

of retorted amalgam, per cord, would be 450 ounces for 30 cords, which at \$20, currency, per ounce, would be \$9,000, leaving a profit of \$4,570. The mine is provided with hoisting power, a small engine driving a simple winding spool by means of a pulley and belt.

*Product of the lode.*—The total yield of the Bobtail lode since the date of its discovery is said by those who have the best means of information to be \$2,500,000; but it has been worked by so many different parties and in such an irregular manner that in the absence of reliable records it is impossible to arrive at anything nearer than a rough estimate of the product.

FISKE LODE.—The Fiske lode is on Bobtail Hill, a little north of the lode just described, and having such a course, as may be seen on the map, that the two veins should intersect each other in the ravine, a little west of the Bobtail mine. This lode is said to have been worked with encouraging results in times past. All operations upon it had been suspended before the writer's visit to the Territory and no convenient opportunity was afforded for examining its underground developments.

GREGORY LODE.—The Gregory lode, the first discovered gold-producing vein in that region which is now the center of the mining industry of Colorado, and bearing the name of its discoverer, is, perhaps, the most widely celebrated of any in the Territory. During the 10 years that have passed since the commencement of work on this lode, it has been the scene of active mining operations and is at present unequalled by any other in the region as regards the general extent of its development; the registered locations on it covering about 4,000 feet, of which nearly half is worked to a depth of about 500 feet. Its relation to the Bobtail lode has been already noted, and the relative positions of the two veins are generally indicated on Plate XXIX.

While the Bobtail may be looked upon as a continuation of the Mammoth, either direct or slightly displaced, the course of the Gregory diverges from the latter at an angle of about 45°. Its point of divergence, if regarded as a branch of the Mammoth, or of intersection, if considered as an independent vein, would be several hundred feet west of the little ravine which divides Bobtail Hill from Gregory Hill, but its exact relations to the Mammoth are not definitely shown by developments thus far made, although claims have

been located beyond the assumed point of intersection and some mining work has been done upon them. It is in the little ravine just referred to that the first discovery of the vein was made.

The most developed portion of the lode begins some 600 or 700 feet northeast of the probable junction with the Mammoth and continues thence in a northeasterly direction some 1,500 or 2,000 feet, divided among and worked by some half-dozen or more companies. Its general course for this distance is 30° east of magnetic north; or, allowing 15° for variation of the needle, is north 45° east, true, or northeast and southwest. Its course in this direction may be traced on the surface down the northern slope of Gregory Hill, across the Gregory Gulch, and over the hill which divides Gregory from Chase Gulch; and along this part of the vein, from the bottom of Gregory Gulch, where is located the mine of the Smith and Parmelee Company, to the top of Gregory Hill, the surface is covered with the shaft-houses, hoisting and pumping works, mills and waste-dumps, of the several companies engaged in mining on the lode. The dip of the vein is nearly vertical, though sometimes inclined either to the northwest or southeast. In the Consolidated Gregory mine the shafts are sunk vertically and are generally within the walls of the vein; further to the northeast, on the ground of the Black Hawk and the Briggs mines, the pitch is southeast, though not deviating far from the vertical; the inclination of the pump-rod in the former showing a dip of 83° or 84°; while still further northeast, in the mine of the Smith and Parmelee, where the vein is divided into two branches, one of which is known as the Gregory and the other as the Briggs, the former dips steeply to the northwest while the latter dips to the southeast.

The relation of the so-called Briggs vein to the Gregory has been the subject of much discussion and some litigation, some claiming that the two are distinct and independent veins; others, that there is but one vein, which is divided into two parts by an intervening "horse" of ground. The probabilities seem to the writer to be in favor of the latter view, though until the developments of each branch are sufficient to determine the limits of the "horse," or to show beyond a doubt that the intervening ground between the two branches is actually only an isolated and inclosed fragment, and not a permanent and continuous part of the country-rock, there will be some

reason for the contrary opinion. The two branches or veins appear at the surface together on the Smith and Parmelee location, and are worked between the same walls for something more than 100 feet. Descending vertically from that point the two diverge, the so-called Gregory dipping about 80° to the northwest, the Briggs at about the same inclination to the southeast, the distance between them, therefore, increasing with the depth, so that at 240 feet below the surface a crosscut shows them to be 72 feet apart.

Horizontally, the two branches diverge in going eastward, the angle of divergence being but a few degrees at first, and further east, so far as opened, the difference in their courses being about 10°—the Gregory having a course of north 45° east, true, while the Briggs has a course of north 55° east, true. The line of junction, or divergence, of the two branches on the west is not a vertical one, but dips to the westward, so that with increasing depth the division of the vein into two branches is found further and further west, occurring near the surface on the western part of the Smith and Parmelee and eastern part of the Briggs location, while on the Black Hawk mine the splitting of the vein into the two branches is about 300 feet further west at a depth of between 200 and 300 feet below the surface.

Eastward, beyond the Smith and Parmelee, the work has not been sufficient, either on the surface or in depth, to determine the relations of the two branches, and whether they reunite, and if so, where, remains to be seen.

The so-called Briggs lode derives its name from the Briggs Company, which is located on the Gregory vein between the Black Hawk and Smith and Parmelee mines. It is said to have been discovered on this property, and, as an independent lode, is understood to be claimed by that company for a considerable distance beyond the limits of their claim on the Gregory itself. The adjoining companies, however, holding that the so-called lode is but a branch and a part of the Gregory, work it as such within the limits of their claims. Some further observations concerning the relations and development of these two veins or branches will be given in the following brief descriptions of the operations of the several companies working on them both.

The country-rock of the Gregory lode is generally similar to that of the Bobtail—a granitic gneiss, sometimes poor in mica, at other times abounding in that mineral, and having the appearance of mica-schist. It frequently

shows parallel bands or lines of structure, or of varied mineral composition, which usually dip flatly to the eastward.

The walls of the vein are not very regular. Sometimes they are quite smooth and well-defined, but usually there is little or no gouge or selvage, and the removal of the vein-matter near the wall leaves a ragged and uneven surface. Where the walls have been left standing sometimes they frequently scale off and fall in large pieces; sometimes belts of highly micaceous character occur, which soften on exposure to the air, rendering the walls very insecure and requiring substantial support. The width of the vein varies from 2 to 5 feet, sometimes expanding to 12 or 15.

The vein-matter is like that already described in the Bobtail—quartzose generally, sometimes a mixture of quartz and feldspar, much of which has a softened, altered character, carrying a large percentage of finely-divided pyrites. Sometimes masses of pure quartz are also densely impregnated with finely crystallized iron pyrites. Crystallized quartz occurs sometimes. Free gold is also found, lumps worth $50 being reported.

As in the Bobtail, there is usually a seam of compact ore, consisting of iron and copper gold-bearing pyrites, associated with the wider belt of vein-matter carrying the ore in disseminated form, as just described. The value of this compact ore-seam varies considerably, but is generally less per ton than that of the Bobtail. Some of the richer lots are said to yield from $150 to $200 coin, per ton, but such are uncommon. In fact, the value of the lode seems to be less concentrated than in the Bobtail, affording a smaller proportion of smelting ore. In their favor, as compared with the Bobtail, the average width of the Gregory is greater. The yield per ton under the stamps varies according to the proportion of compact and richer pyrites occurring with the poorer vein-matter. The latter yields alone from 5 to 6 ounces per cord, or $10 to $13, in coin, per ton, while the average yield of the Black Hawk rock for six months, crushing everything together, is stated at from $20 to $25, coin, per ton.

The same distinction observed in the Bobtail, that the fine-grained copper pyrites is the richest gold-bearing mineral of the ore, prevails also in this vein. But little galena, and less zincblende, is found associated with the ores of the Gregory.

The distribution of the ore is variable, sometimes occurring in seams 2 or 3 inches wide with intervening bands of poor rock, sometimes expanding to 2 feet or more in width, sometimes pinching out altogether, leaving the vein filled with barren matter, consisting of hard quartz and feldspar. The pay-seam is usually on one wall or the other, but does not seem to follow either uniformly throughout the length of the lode. The prominent working mines on this lode are, beginning about 600 or 700 feet northeast of the junction with the Mammoth lode, as follows:

| | Feet. |
|---|---|
| Narragansett | 400 |
| Consolidated Gregory | 500 |
| Black Hawk | 300 |
| Briggs | 250 |
| Smith and Parmelee | 300 |

Southwest of the first named of these are other claims, covering in all more than 1,000 feet, on which some work has been done, while northeast of the last named the lode has been claimed and somewhat developed for another thousand feet, but all of these claims were idle at the time of the writer's visit.

A longitudinal section of the lode will be found on Plate XXX. This section is not prepared from actual survey. So far as the writer is informed no careful survey has ever been made of any of the mines on the lode, and the existing records concerning the occurrence of ore in the vein are very meager. The section here given is prepared from verbal statements made to the writer by officers of the mines. Some of the notes were obtained in 1868, and the sketch here given does not claim to represent with unquestionable accuracy the extent of ground that has been worked out. It is the object of this section, as well as of the other two on the same Plate, to represent in a more impressive manner than can be done by verbal statement, the length, relation to each other, and the general manner of development of the several claims on three of the most important lodes of the district. Especially the Bobtail and portions of the Burroughs are striking illustrations of the disadvantages of subdividing such veins as these into short, independent

claims, involving for each the necessity of sinking expensive shafts, providing hoisting works, and sustaining separate organizations for management or superintendence.

*Narragansett.*—The first of the above-named companies, the Narragansett, own 400 feet of the lode, and have opened their mine to the depth of 450 feet. The greater part of this work was done several years ago. Costly hoisting works and crushing machinery were provided at the mine, but operations were suspended in 1866, as the results then obtained were not satisfactory. This condition, it is said, was chiefly due to the want of an efficient method of treating the ores. In 1868 work was resumed by parties who leased the property, and the main shaft was sunk an additional hundred feet. It is said that encouraging results were obtained, but about this time the work on the Bobtail lode was suspended, and such is the connection between the two veins that the water of one affects the other. As the pump on the Bobtail ceased to drain that lode, the water increased so much in the Narragansett that operations were again suspended. The mine was therefore inaccessible to the writer. The work represented in the accompanying section is in accordance with statements made to the writer by several parties somewhat acquainted with the mine, but more stoping has probably been done above the lower levels than is indicated in the sketch.

*Consolidated Gregory.*—The Consolidated Gregory Gold Mining Company own 500 feet of this lode, working as one mine what was formerly divided up into several short, independent claims. The mine is opened by three shafts, of which the central one is the chief, having reached the greatest depth and being fitted up in the most substantial manner, provided with pumping and hoisting machinery and other facilities for permanent and extensive operations. This shaft was begun from the surface by the Consolidated Company, and has reached a depth of over 400 feet. The east shaft, sunk by the former owners, was abandoned by the new company as a means of working, and only kept open for ventilation. The west shaft is used for hoisting, the power for that purpose being transmitted from the machinery at the central shaft. The first level is at a depth of 230 feet below the mouth of the central shaft; the second level is 70 feet lower, and the third level is 60 feet below the second. The good ground, in the upper portion of the mine, has been pretty much

worked out, but, when seen by the writer, there were reserves of considerable extent in the lower levels. The vein in the bottom of the mine was looking very well, being from eight to twelve feet wide in the third level and carrying a strong seam of solid ore, as well as a wide belt of good stamp-rock. This mine usually sends all its ore to the stamping mill without selection of the first-class. According to the statement of the mining captain, about three-fourths of the entire vein-matter is fit for crushing, of which one-tenth part would be suitable for smelting, if desired. The average product of all that is sent to stamps is stated at six ounces of retorted amalgam per cord, equal to $12 or $15, in coin, per ton. The present owners of the mine are developing their property with a view to permanent operations and economical management. The central, or main, shaft has been sunk vertically to its present depth, and timbered up in a very substantial manner. It is 6 feet wide by 11 feet long, in the clear, divided into two compartments, one for hoisting and the other for pump and ladder-way. It is timbered from top to bottom with 8-inch and 10-inch squared timbers, framed in sets that are placed three feet apart vertically. The ground through which the shaft passes is sufficiently firm to allow of sinking for 50 or 60 feet without support, so that the timbering can be put in from below upward. When a suitable depth has been reached to make timbering desirable, a firm support is afforded for the first or bottom set by cutting the necessary "hitches" in the solid rock and heavy timbers are put in place across the shaft, resting on the foundation thus provided. When the first set, consisting of the two end pieces and two wall-plates, framed together at the corners, is in place, the cross-timber for the partition resting in gains cut in the larger pieces, the posts or studs, three feet high, are raised at the corners and in the middle, opposite the partition, and on these the succeeding set is laid. Each set, when in proper position, is strongly secured by spiling, or wedges, driven in firmly between it and the wall-rock at each corner and opposite the partition timbers, so that it is immovable, independently of other support. The timbering of the shaft is cased with plank on the outside, and the space between this and the wall-rock, when everything is completed, is filled with waste-rock. The hoisting compartment is likewise lined with 2-inch plank inside, to facilitate the passage of the hoisting bucket.

In the pumping compartment there is an excellent ladder-way, with platforms about 15 feet apart. The pump consists of an 8-inch plunger, placed at 230 feet below the surface, with a 9-inch column of cast-iron pipe above it, reaching to the surface. Below it is a lifting pump, reaching to the bottom of the mine; the latter consisting of the working barrel, with the wind-bore attached below, and sufficient length of pipe above to reach the cistern of the standing pump, higher up, is suspended in the shaft by means of a chain, that is attached to a stout screw, six or eight feet long. The screw passes through a nut, which rests on a stout and firmly-secured timber. By turning the screw, the whole of the sinking pump apparatus may be lowered as the sinking of the shaft proceeds, and the wind-bore thus kept at the very bottom, additional pipe being added at the top as it becomes necessary in the progress of the work.

The wind-bore is a very heavy casting, two inches thick, perforated with inch holes, and is sufficiently strong to stand the blows of the rock that may be thrown against it during blasting, without any protection. The working of the pumps is effected by means of a pump-rod, operated in the usual way by machinery at the surface. The rod is an 8-inch square timber, joined by bringing the squared ends together, without splice or scarf, and secured by straps of iron on two sides, eight feet long, four and a half inches wide, and five-eighths of an inch thick, and bolted through with inch bolts. The engine at the surface, used for pumping at this shaft and for hoisting at both shafts, is a plain horizontal cylinder, 14 inches in diameter by 26 inches stroke, supplied with steam by one flue boiler.

Hoisting is done with a bucket. The winding apparatus is driven by belting. As this method of hoisting is in general use in Colorado a somewhat detailed description of it here may serve as an example. The contrivance is very simple, and, though not well adapted to deep shafts or heavy work, it answers its purpose very well in shallow mines, and gives much satisfaction. The general method of arrangement is indicated in Figs. 1 and 2, on Plate XXXI.

The drum, or spool, *A*, on which the rope is wound, is placed near the mine shaft, so that the rope passes from it over a pulley, *b*, and thence down the shaft. This spool, about 4 feet in diameter, is fixed on an iron shaft, *c*,

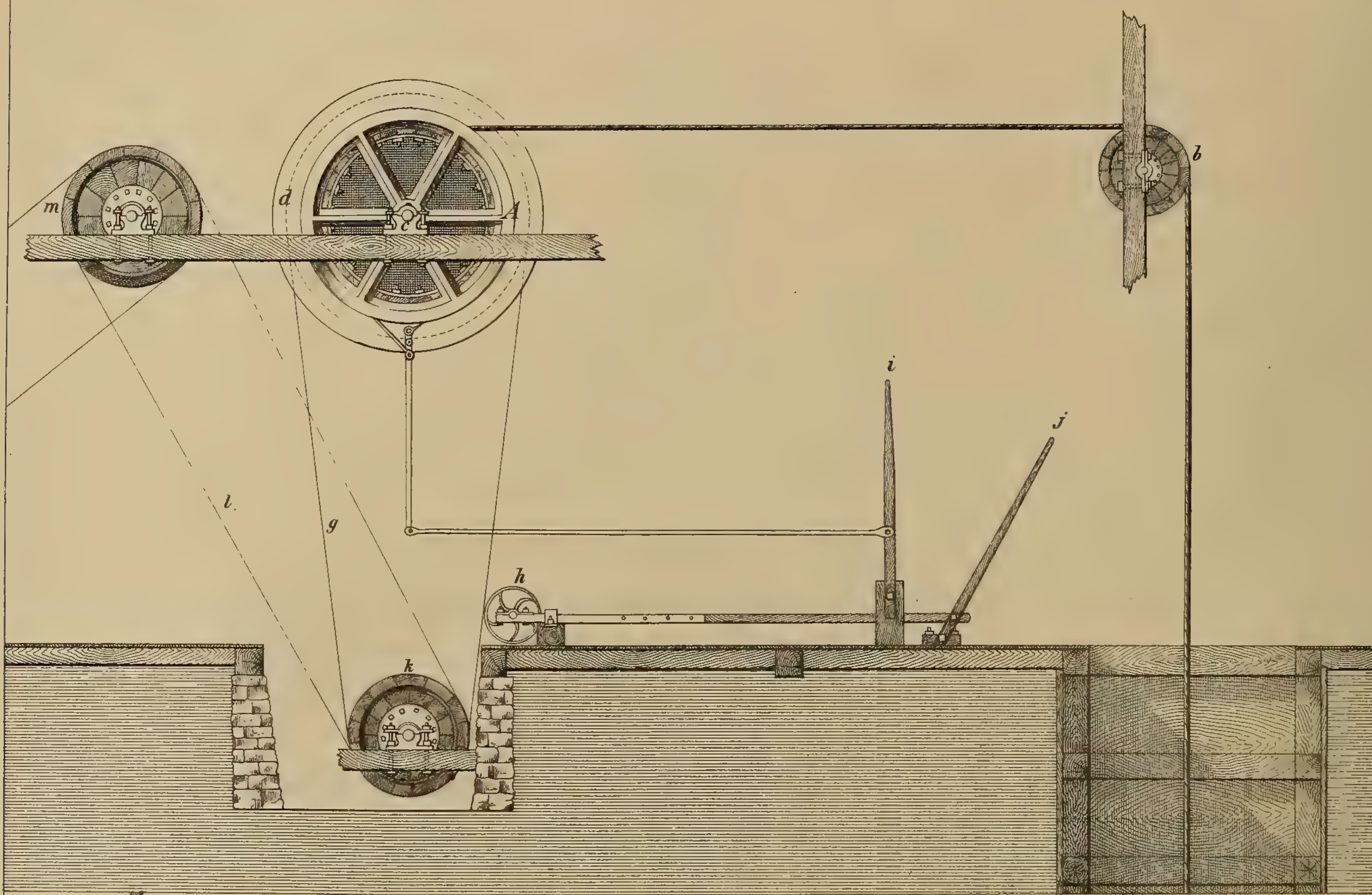


*Fig. 1.*

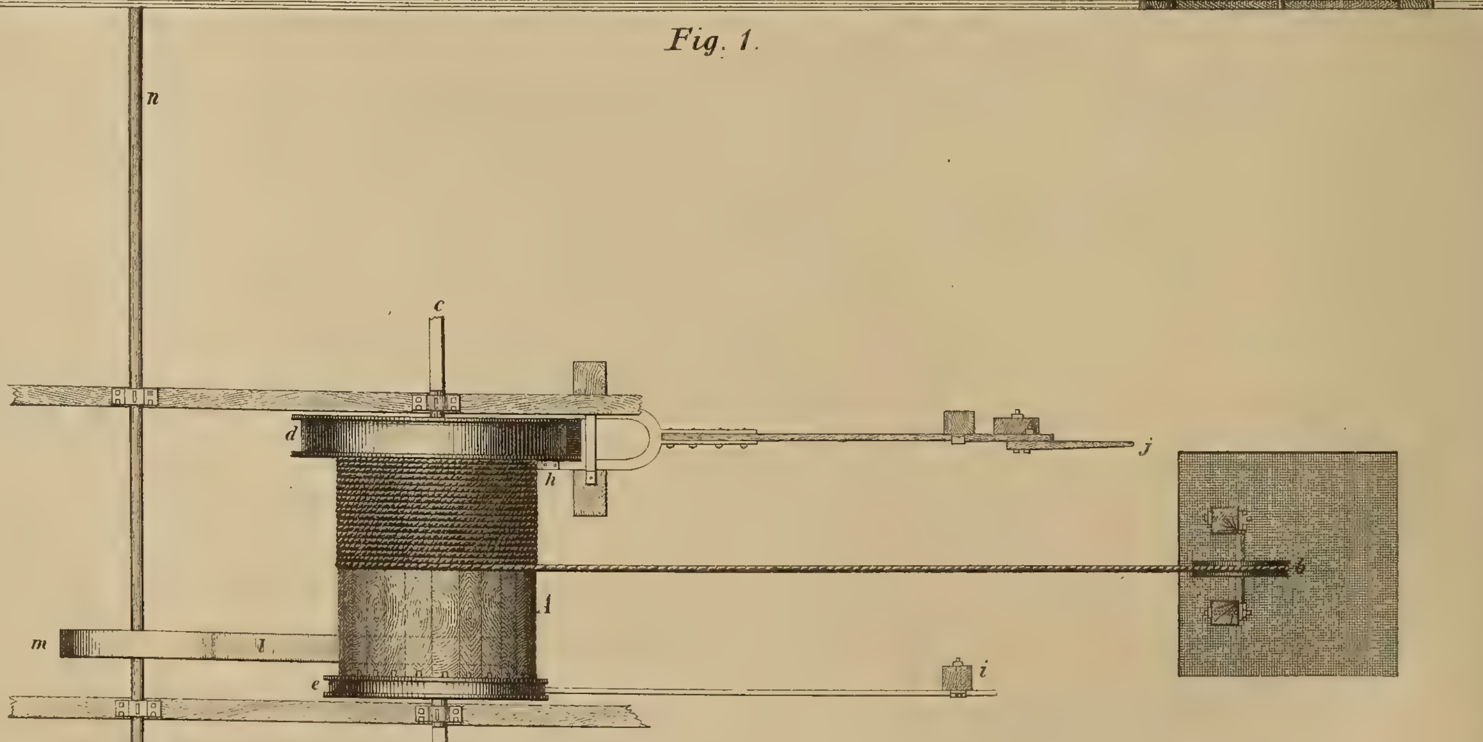


*Fig. 2.*

Scale: $\frac{1}{48}$.

having at one end a pulley, *d*, of somewhat larger diameter, and, at the other end, a brake-rim, *e*. Motion is communicated to the pulley *d*, by means of a driving pulley, directly beneath it, and an 8-inch belt, *g*. This belt is slack and imparts no motion to the spool unless the tightener, *h*, be applied to the belt, by means of the lever *j*, which is done by the attendant, standing at the mouth of the shaft, whenever it is desired to hoist a bucket from the mine. On withdrawing the tightener the spool is held firmly, or its reverse motion is controlled, by means of a brake, which is a 4½-inch iron band, encircling the spool at the rim, *e*, and applied by the lever *i*, as indicated in the drawing. The pulley, by which the belt *g*, is driven, is on the same shaft with, and concealed from view by, the pulley *k*, to which motion is communicated by the belt *l*, from the pulley *m*, which receives its power directly from the engine. The pulley *m*, drives a long shaft, *n*, extending from the building in which the machinery is inclosed to the other shaft-houses of the mine, where winding apparatus of similar character is set in motion in the same manner as that just described. Power is sometimes transmitted in this way a distance of several hundred feet, from an engine to a remote shaft-house.

A detailed statement of the costs of sinking and timbering these shafts is not in the possession of the writer, nor is such information readily obtained in Colorado, as but little attention is paid to the classification of accounts or analytical statements of the varied expenses of mining rock. Labor is generally employed by the day at $3 50, in currency, for miners, and from $4 to $6 per day for mechanics. Drifting, on contract,—the miners furnishing their own supplies, except steel,—costs from $15 to $20 per foot; sinking $25 to $55 per foot. The west shaft, being carried down 6 feet by 10 feet, cost $27 50 per foot; the central shaft 8 by 13 feet cost at first $45 and later $55 per foot. Square timber and lumber cost $35 per 1,000 feet, board measure. The owners of this mine have recently built a large mill containing 50 stamps, which commenced operations late in 1868. The average yield of the ore has been already stated, but the writer was unable to obtain any detailed statement of the mill's production.

*Black Hawk.*—The claim adjoining the Consolidated Gregory on the east is 300 feet in length and is owned and worked by the Black Hawk Gold

Mining Company. The same company own other claims on the same lode, one of them 200 feet in length, about 1,200 feet further west, between the Narragansett mine and the Mammoth lode; the other 250 feet in length, about 1,000 feet further east, on the eastern extension. They also own, as already stated, 76 feet on the Bobtail, now lying idle, besides some less developed property in the region; but their work at present is concentrated on the 300 feet of the Gregory first referred to.

There are three shafts, one central and one near each end of the mine. Of the two latter the westernmost has been abandoned, so that operations are carried on only through the other two, which in August, 1869, had reached a depth of 576 and 531 feet. In the northeastern part of the mine the vein, at a depth of about 300 feet below the surface, is divided into two branches, which are generally considered, although the connection had not been actually traced, as the same branches that in the claims further east are distinguished as the Gregory crevice, on the northwest side, and the Briggs crevice, on the southeast side. The line of junction of these branches appears to be between the eastern and the central shafts, occurring, as has already been said in the foregoing, further and further west as the depth increases. Thus, all the ground in the upper portion of the mine and for the whole depth west of the central shaft has been worked as one vein, while below a depth of 250 or 300 feet, in the eastern portion, the two branches have been recognized. It should be observed that in the eastern, lower portion of the mine, where the Briggs has been chiefly worked, the Gregory is small, poor, and so far not worked.

The general course of the Gregory or main crevice on this property is north 45° to 47° east, true, while that of the Briggs, near its point of divergence from the Gregory, is north 50° to 52° east. The dip of both branches is southeasterly, though not deviating far from the vertical. The average width is three or four feet, though in the western part of the mine, where appearing as one crevice only, it expands in places to twelve or fifteen feet. The pay-ground, as already shown, consists usually of a solid seam of pyrites, with a course of vein-matter impregnated with the same. The compact seam is frequently two or three feet wide. The whole of the vein-matter is usually taken out and crushed together in the stamping mill, yielding, it is said, from $20 to $25 per ton, in coin. The bottom of the mine, where accessible, was

showing an excellent seam of ore. The mine has been worked almost altogether by underhand stoping, and nearly all the ground known to be productive has been taken out. The shafts are now being sunk in the hope of getting ground opened in advance of the demands of the mill. The manager and captain of the mine are experienced men in their business, and appreciate the advantages of regular and systematic mining, but when money is needed and must be produced by the mine, the ore must be taken out with less regard for economy in the future than for the pressing necessities of the present.

During 1867 the mine was worked very profitably, as will be seen further on, but the production was stopped almost entirely in January, 1868, by the breaking down of the pump. Previous to that time the water, of which there was and is a great deal, was removed by a small and overworked pump that finally gave out entirely and suffered the mine to fill up with water. During the first half of 1868, the principal work done was to obtain and put in place a new and efficient pump. This was accomplished in August of that year. The pump is the largest and most costly of any in the Territory. It is established in the central shaft and consists of two 14-inch plungers, or force-pumps, one at 220 feet, the other at 440 feet below the surface. A draw-lift pump is attached below the second plunger. The column is 15 inches in diameter, and is made of riveted iron plate, one-fourth of an inch thick, like those in use in California and Nevada. The pipe of the column is made in sections 15 feet long, with a stout cast flange at each end, by which they may be connected together. The working-rod is an 8-inch square timber, in sections about 30 feet long, joined by splice similar to that shown in Fig. 6, Plate IX.

The shaft, which is sunk vertically to a depth of 220 feet, inclines at that point at an angle of 86°. In order to accommodate the pump-rod to this change in direction, the continuation of it is clamped to the vertical part in manner shown in the figure. The main or vertical rod passes through guides below the joint in order to prevent vibration and to counteract the lateral force exerted by the inclined portion of the rod.

The pump runs on a five-foot stroke and makes five strokes per minute. It is operated by means of a "bob" and driving-wheel at the surface in the usual way, but the power is transmitted to the pumping-gear from the engine at the eastern shaft, which is between 100 and 150 feet distant, by means of

line-shafting. The engine, which is used for hoisting at both shafts and for driving a 20-stamp mill, communicates its power by means of a pulley and belt to a 4-inch shaft, which is extended, with diminished diameter, in the direction of the pumping shaft; but as the latter is higher up the hill, some 30 feet or more, it is necessary to disconnect the line-shaft twice, belting upward, in each case, to connect the detached parts. From this line-shaft the power is transmitted to the pump-gearing by means of a pulley and belt. This arrangement is said to work satisfactorily by the engineer in charge, but such a method of driving a pump of so large dimensions and required duty as the one just described is not to be recommended. The shafting is liable to get out of line, involving not only the necessity of repairs, but an interruption in the raising of the water. Powerful tighteners are required on the belts, and when the engine is running stamps and hoisting too, the pump works very irregularly. The pump was built by Hodge & Christie, of Detroit. Its cost for all the iron work was 10 cents per pound at the shop; freight to the mine 9 cents. The total costs of providing and placing the pump and its appurtenances, not including any part of the engine, is stated at $33,000. The engine used for pumping, hoisting, and running the 20-stamp mill is a plain horizontal cylinder of 20 inches diameter by 42 inches stroke, supplied with steam by two boilers, 16 feet long by 4 feet diameter; burning about five cords of wood per day.

Hoisting is done by iron buckets, containing about 800 pounds of rock. The winding apparatus is similar to that already described on the Consolidated Gregory, and is operated by means of belting, set in motion by the application of a tightener, and controlled, in lowering, by a brake.

There are two stamp mills belonging to the company, one containing 20 stamps set up at the mouth of the eastern shaft, and run by the same engine that does the pumping and hoisting; and one containing 60 stamps located in the town of Black Hawk, near the mouth of Chase Gulch. The machinery and methods of operation employed in them will receive attention further on when the general treatment of the ores of the district will be described.

Owing to the lack of statistical information on the subject the writer is unable to furnish such minutely detailed statements as are desirable concerning the costs of operation, the yield of the ore, and the production of the mine.

The following data, however, furnished by the superintendent, Mr. Congdon, from the company's books, and reliable so far as they go, give some general results.

During 1867 the product of the mine was 12,193¾ ounces of crude bullion, yielding in currency $279,647 76, or $22 81 per ounce. The number of cords or tons from which this product was obtained is not stated, but the yield of the rock at that time is said to have been 10 ounces of bullion to the cord. Assuming this to be correct, the quantity worked would have been 1,220 cords, which, at a trifle more than eight tons to the cord, would be equal to 10,000 tons. On this basis the yield of the rock would have been $27 96 per ton, in currency, or $20 11, in coin, allowing the average value of the ounce of amalgam to be $16 50. The yield of 10 ounces of bullion to the cord is much higher than that now obtained, and is perhaps overstated. Another method of arriving at the quantity is by considering the average amount treated weekly, which is stated at about 32 cords. This in fifty weeks would amount to 1,600 cords; and allowing seven and a half tons to the cord, which is, perhaps, more nearly correct than eight tons, we have a total of 12,000 tons of ore, of which the yield per ton would be $23 30, in currency.

During this period the costs were as follows:

| | |
|---|---|
| Mining expense | $137,214 65 |
| Milling expense | 39,998 02 |
| Teaming expense | 17,212 96 |
| | 194,425 63 |

If the quantity of ore produced was 12,000 tons, the cost of mining was $11 43; of milling, $3 33; of teaming, $1 44; and of all the foregoing together, $16 20 per ton, in currency.

| | |
|---|---|
| The total product being | $279,647 76 |
| And the above named costs | 194,425 63 |
| The excess of yield over costs was | 85,222 13 |

During the latter half of 1868, when operations were resumed, there were produced $3,942\frac{32}{100}$ ounces of amalgam, worth $88,379 82 in currency. If the quantity of ore be assumed in about the same proportion to the product as in the former case—that is, say, one ounce of amalgam per ton—we have 3,942 tons, producing $22 42 per ton in currency.

The costs during the same period were, for mining expense, $45,206 86, and for teaming expense, $6,441 42; which, assuming the quantity to be as above, are equal to $11 52 per ton of ore for mining, and $1 63 per ton for hauling. Milling expenses during that year were a little more than counterbalanced by the profits derived from working custom ores; the actual costs, however, were not less than $20 per cord, or $2 66 per ton, making a total of $15 81 per ton, exclusive of office expense and interest. Judging from the data given below concerning the operations of 1869, the number of tons above given is too small. By increasing this number, the yield per ton and the cost of working per ton will be correspondingly decreased.

During the first half of 1869 there were produced 3,177 ounces of retorted amalgam, worth $65,755 94, in currency. The quantity of ore is stated at $622\frac{3}{4}$ cords, equal to 4,670 tons. The average yield per cord is $5\frac{1}{10}$ ounces of retorted amalgam. During this period the mining expense was $37,833 80, and the teaming expense $2,899 70. Accepting 4,670 as the number of tons worked, we have a mining expense of $8 10; of teaming, 62 cents; and estimating milling, as before, at $2 66, we have a total cost for the above items of $11 38, and a yield per ton of $14 08 in currency.

*Briggs.*—The Briggs Gold Mining Company's property adjoins the Black Hawk on the east. The mine is 250 feet in length and opened by two shafts, one of them 71 feet from the east line, the other 51 feet further west. Both are sunk on what is considered the Gregory crevice, but the southeastern branch of the vein, the Briggs, has been worked to a greater depth and yielded a larger amount of ore than the Gregory. On the eastern end of this property the two branches are near together at the surface, diverging, however, slightly in depth. Horizontally, the branches are found to diverge between the two shafts, the line of junction dipping westward, so that, as has been already shown, at a depth of 300 feet the division of the vein into two parts occurs on the Black Hawk property.

The course of the Gregory crevice is about north 45° east; that of the Briggs north 55° east, true. Both branches dip slightly to the southeast. Near the surface the two branches are said to have been worked as one vein, but being now entirely filled with old stulls and waste-rock, no opportunity is afforded for studying their relations to each other. At the depth of 100 feet or thereabouts they are worked separately from the point where they diverge, leaving the tongue or wedge of barren country-rock standing between them.

The Gregory crevice is worked to a depth of 130 feet for the whole length of the property, and below that has been found rather unpromising, while the Briggs, on the eastern part of the ground, has been worked to the depth of more than 400 feet and found very productive.

The Briggs Company have a large mill, containing 50 stamps, located on the mine between their two shafts, so that the ore is delivered for treatment with the least possible expense for handling. The power for driving the mill is also applied to the hoisting and the other necessary work of the mine, and is furnished by a steam-engine of 22½ inches diameter of cylinder. Steam is supplied by two tubular boilers. The hoisting power is communicated by belting to the winding apparatus, which is, in most respects, similar to that already described.

This mine is said to have been one of the most productive and profitable of any in Colorado. It has, however, suffered some embarrassments, and in the summer of 1868 had, after a period of idleness, resumed operations under different owners. The production had therefore been suspended, the mill being worked on custom ore. Since that time it is reported as having been worked very successfully.

The average value of the first-class ore produced by this mine appears from 136 tons sold, during the first half of 1869, at the Smelting Works, containing 5¼ ounces of fine gold and 10½ ounces fine silver to the ton. During seven months of 1869 the product of the milling rock of this mine was about $55,000. The total product, including smelting ore, was $70,000 currency, or about $10,000 per month. The mine is reported to be steadily improving in productiveness and profitable operation.

*Smith and Parmelee.*—The Smith and Parmelee Gold Mining Company own and work the next adjoining mine on the east, claiming 300 feet on the

so-called Gregory crevice and 800 feet on the Briggs. Both veins, or branches of the same vein, are worked by this company for the distance of about 250 feet, measured from the Briggs claim, beyond which neither has, so far, been found very productive. The Gregory branch has been worked to the depth of about 150 feet, below which it has not been much developed, the work having been chiefly confined in depth to the Briggs branch. This latter has been worked to a depth of more than 550 feet, and has furnished by far the greater portion of the whole product of the mine. It is on this property that the divergence of the two branches is so far found to be the greatest, but little being known of their relations to each other further east. In the crosscut, at a depth of 240 feet, they are 72 feet apart. The two branches maintain on this property the courses observed further west with considerable regularity, that of the Gregory being generally north 45° east, and that of the Briggs north 55° east, true; but so far as observed, that is to a depth of 150 or 160 feet, they have a more divergent dip, that of the Gregory being about 80° to the northwest, while that of the Briggs is generally about 80° to the southeast.

The Briggs has received the most development. Its average width is 3 or 4 feet. Its walls are not always well defined. The filling of the vein is generally similar to that already described. Seams of solid iron and copper pyrites, chiefly the former, occur with belts of quartzose and feldspathic material, carrying ore more widely distributed through the mass. In the bottom of the mine, where, by reason of the underhand stoping and lack of reserve ground, the only opportunity is afforded of seeing the ore-vein in place, there was a strong seam of iron and copper pyrites visible at the time of the writer's visit. The mine for some time past has been producing at the rate of 600 or 800 tons of ore per month for stamping, besides a small proportion of first-class, of about the same quality as the first-class ore of the Briggs Company. The milling ore is said to produce six ounces of crude bullion to the cord, worth $100 in coin, or $13 to $14 coin per ton. The costs of mining and milling are stated at about $12 in currency per ton.

The mine is provided with a 25-stamp mill, conveniently placed at the mouth of the shaft. It has been rebuilt within the past year and has great advantages for economical work. The engine in the mill furnishes power for hoisting and pumping from the mine.

Beyond the Smith and Parmelee is the claim of the New York Gold Mining Company, on which a shaft has been sunk between 200 and 300 feet in depth. The claim, however, is disputed by the Smith and Parmelee. Nothing has been done on it for some time. Still further east are other claims, covering several hundred or a thousand feet, but not yet much developed.

Bates Lode.—The Bates lode is several hundred feet northwest of the Gregory, and nearly parallel to that vein, or rather to the so-called Briggs, having, so far as observed by the writer, a nearly identical course with the last named, north 55° east, true. It is traced on the surface down the northern slope of Gregory Hill, across Gregory Gulch, and over the hill dividing the last named from Chase Gulch. It has been opened and worked to a considerable depth for about a thousand feet in length, and claims are located on it for a still greater distance. On the lower part of Gregory Hill, where it is commonly known as the Bates-Hunter lode, there are several short claims that have been worked by private parties; one of these claims, 160 feet in length, belonging to Borem, Mellor & Company, has been worked by them to a depth of 100 or 200 feet, producing excellent milling ore at a handsome profit to the men engaged in it.

Further to the northeast, the Rocky Mountain Gold Mining Company have a claim of 250 feet, located just in the bed of the Gregory Gulch, on which they have sunk three shafts to the depth of 200 or 300 feet, having on the surface a liberal provision of hoisting and pumping machinery, comprising an excellent engine of 40 or 50 horse-power, with boilers and winding apparatus.

*Union.*—Adjoining their claim on the east is the Union mine, 300 feet in length, and worked to a depth of 350 or 400 feet. The vein is 5 or 6 feet wide, on an average, but expanding sometimes to 15 or 20 feet, and pinching up in places to a few inches. In general, however, it appears in the Union mine to be one of the strongest and most uniform lodes in the Territory. The mine has been opened by two shafts, of which the western is the deeper and the main shaft; the other is not in good working condition, and is only useful as a ladder-way and air passage. The mine has been pretty thoroughly worked out to a depth of 250 feet, but, when visited by the writer, had more

ground opened and available for stoping than is usually found in the producing mines of the district. The vein, where passed through by the shafts, had been found generally small, but the levels driven in either direction from the shaft had cut good bodies of ore. In the first level, 150 feet below the surface, east of the eastern shaft, where the vein was standing, there was a seam of solid ore, consisting of iron and copper pyrites; this was near the north wall, and separated from it by a gouge or selvage of soft clay, some six inches thick. Between the seam of pyrites and the south wall, the vein, 4 or 5 feet thick, was filled with good milling ore, consisting of siliceous, feldspathic matter, thickly impregnated with pyrites. This character of pay-ground was continuous to the end of the drift, some 60 or 70 feet in length. In the lower levels, in the eastern portion of the mine, the vein was smaller, and had the appearance of being somewhat disturbed. West of the shafts the ground has been worked up to the line of the adjoining company, and, as is claimed by the latter, beyond the line, which has caused some litigation. In the bottom the vein maintains its average width, carrying two seams of compact ore, a foot apart, and 18 inches wide in the aggregate, the space between being filled with good milling ore. The ore of this vein carries a much larger proportion of galena and zincblende than either the Gregory or the Bobtail, though the predominating mineral is the iron and copper pyrites, and chiefly the former. The main shaft of this mine is being carried down in a workmanlike manner, substantially timbered with square sets, generally similar to that described in the Consolidated Gregory. The machinery on the surface is a small portable engine, having a 6-inch cylinder, used for hoisting; the winding apparatus consisting of the drum operated by belting and controlled by brake, in the manner common in this region. The company have a 20-stamp mill in Chase Gulch, about a half mile from the mine, in which the lower-grade rock, or that of second quality, is crushed and subjected to the common process, while the higher grade, or first-class ore, is selected for treatment by other methods. This is said to contain about 5 or 6 ounces of fine gold and 20 ounces of silver to the ton, worth from $120 to $140, in coin. Concerning the yield of the rock, or detailed costs of operations, but little definite information was found available. The low-grade ore is said to yield, in the ordinary stamping process, from 4 to 12, averaging probably 5

or 6, ounces per cord, or $12, coin, per ton. Concerning costs of production, it is said by the president of the company that the whole expense of operation is more than paid by the product of this low-grade rock, leaving value of the first-class ore as a surplus of profit to the company.

The Bobtail, Gregory, and Bates lodes have been described as having convergent courses, which, if continuous, would lead them all to a union with Mammoth lode. This vein extends in an east and west direction, from near the western terminus, so to speak, of the Bobtail lode. It has been traced thence for a distance of 2,000 or 3,000 feet, and is covered by mining claims, on which work has been done, with some success, near the surface, but not generally below a depth of 200 feet. The deepest of the several mines on the lode is that managed by Judge Morse, of Central City, which is located near the assumed point of the junction of the Gregory with the Mammoth. Several shafts have been sunk on this vein, one of them over 300 feet, finding a large vein, but filled with iron pyrites that is almost entirely wanting in the precious metals so commonly associated with this mineral in Colorado. Not much drifting has been done in depth, so that but little is known of the lode except as revealed by the sinking of the shaft. Extending the line of this lode in a westerly direction, but a little distance beyond the point to which it has been traced, and crossing Spring Gulch, we come to Quartz Hill, which has been, and still is, the scene of active mining enterprise. This hill has a general east and west trend, forming the divide between Nevada Gulch, on the north, and the Illinois and Leavenworth Gulches, feeders of Russell Gulch, on the south. On the east it is drained by Spring Gulch, which, uniting with Nevada Gulch, just above Central City, becomes thus a feeder of Gregory Gulch, about a mile above its junction with North Clear Creek. The hill, in that part most occupied by mining operations, rises to an altitude of 600 or 700 feet above the level of the streams at its base. These several gulches were the sources of large quantities of gold in the early days of placer mining in these regions, and some of them continue to yield liberally, under the simple operations of sluice mining. The rich character of the washings of the surface naturally led to the prospecting of the hill for the deeper sources of the metal, and many lodes have been discovered, some of which have been developed to a greater depth than

any others in the Territory. The lodes inclosed in this hill have generally a nearly east and west course, with a nearly vertical dip, but inclined slightly toward the south, closely resembling the Bobtail lode in these respects. The country-rock of the hill is essentially the same as that already described further east. It generally has the features of gneiss, though often quite granitic in character. The veins average perhaps somewhat less in width than those that have been already described, but they are regular, well-defined, and equally promising as to permanence. The ores have the same general character, with some differences that will be noticed below. Among the many lodes that have been opened and partially developed the best known are the Burroughs, Kansas, Gardner, and Illinois, on that part of the hill that has been longest known and worked to the greatest depth, while further west are the Flack, American Flag, California, and others, which are of increasing importance. The ores of these latter are distinguished by the large proportion of argentiferous galena, zincblende, and silver sulphurets that are associated with the iron and copper pyrites, giving them sometimes a high value in silver, but rendering difficult or practically impossible the extraction of the gold by any simple process yet available. Some of the more prominent lodes of Quartz Hill will be described in the following pages, selecting for purposes of illustration one or more of the leading or characteristic mines that are located on them.

Illinois Lode.—The Illinois lode is traced along the north side of the hill, not far from its crest. The principal developments on it have been made in the North Star mine, owned by a company in Chicago, and managed by Mr. George Mitchell. This mine was worked by the company referred to until 1869, when it became involved in financial difficulties, and operations were embarrassed, if not suspended. The mine was opened by two shafts, one of which was sunk to a depth of 234 feet, and at 160 feet below the surface a level was driven over 700 feet in length. Earlier owners, who had taken off the "top quartz" and obtained a good deal of gold from the surface diggings, had sunk three shafts to the 160 foot level, but as the ground passed through was not particularly rich, and the ores found were more refractory than the surface product, the work had been abandoned, until again resumed by the new company, who carried the level eastward, and sunk the eastern shaft to the

depth just named. From these developments the vein appears to have a course of north 60° east, true, though its average course for a longer distance than that observed is said to be more to the eastward, and thus more nearly parallel with the other neighboring lodes further south, that trend north 85° east. Its dip is to the south 84°, and so far as sunk upon is very regular. The average width is about two feet, frequently expanding or contracting to greater or less dimensions. Its walls are generally smooth and well defined, sometimes polished, grooved, or striated, showing indications of movement. Usually there is a soft "gouge," or seam of clay between the walls and the filling of the vein. The latter is chiefly quartz; sometimes white, hard, and amorphous, carrying little or no valuable mineral; sometimes showing a sparse distribution of crystallized iron pyrites throughout its mass; but most commonly the vein-matter is a mixture of siliceous and feldspathic material, in which occur small seams or scattered particles of pyrites, making a very fair quality of stamp-rock, and, as in the other veins already described, associated usually with a narrower but solid seam of compact pyritous ore. The latter is from two or three to ten or twelve inches thick, and furnishes a small proportion of smelting ore. This proportion appears, from all available data, to be between one-twentieth and one-tenth of the whole number of tons produced. The valuable mineral in the vein consists chiefly of iron pyrites, with a lesser proportion of copper pyrites and, as a characteristic feature, some arsenical pyrites; with these are associated some zincblende and galena. The yield of this ore in silver is shown by the assays of Professor Hill to be larger than is usual in the pyritous ore veins of the district, the average of 42 tons sold by the mine at the Smelting Works, during the summer of 1868, being about four ounces of fine gold and twenty ounces of fine silver to the ton. The yield of stamp-rock during a run of thirty-four weeks in the summer of 1868, when 200 cords, or 1,500 tons, were supposed to have been treated, was 1,538 ounces of crude bullion, or about one ounce per ton. The average value of the ounce of this bullion is stated at $15 50, coin.

The filling of the vein is generally soft, so that much of it may be removed with a pick, requiring comparatively little blasting. This facilitates considerably the working of the ground, both drifting and stoping being done for somewhat lower prices than in the majority of the veins in the district.

The present openings of the mine are near the west end of the property. Several shafts were sunk there by the earlier owners, only two of which have been adopted by the present management as the means of working the mine. Of these the westernmost is about 75 feet from the west boundary; the other, the east shaft, about 130 feet further east. The first level at 160 feet depth passes through good ground, some productive stopes having been worked above it, while the second level, 60 feet deeper, was just being opened when visited by the writer; an excellent vein of ore was said to have been opened in this level and in the bottom of the shaft, but it was under water at the time referred to, owing to a temporary interruption of the hoisting work. The North Star Company assumed the management of the property in 1866 or 1867, and devoted the first year or something more to putting the mine in shape for permanent and systematic working. The two shafts required straightening, enlargement and retimbering, and as the mine had no productive ground then opened and ready for stoping, a considerable outlay was required in preliminary work. Hoisting and stamping machinery was needed, and as this was provided on a liberal scale and with a view to extended operations, the expense incurred was large. Meantime the product of the mine was little or nothing, and as the capital furnished by the company was hardly adequate to the execution of the plans proposed, the work has constantly been embarrassed.

The two shafts are well timbered up, divided into two compartments, one for a ladder-way, the other for hoisting. The levels are provided with tramways and wagons; the stoping is carried on overhand; the broken rock is first assorted on the stulls, so that whatever is too poor to pay for hoisting is left underground, while the ore is dumped into chutes, or "mills," constructed at convenient intervals along the level, and thence is loaded into the tram-wagons without handling or shoveling, and so moved to the hoisting shaft and dumped into the bucket or "skip." This last-named contrivance, which is a self-discharging apparatus, is illustrated in Fig. 3 on Plate XXXII.

The body of the skip, *S*, is a rectangular vessel, or bucket, made of boiler-plate, and capable of holding about 20 cubic feet of ore or water. Moving in the shaft it is carried in an upright frame consisting of two sides, *a*, *a*, and two cross-pieces, *b*, *b*. The sides of this frame are bars of wrought iron, the lower ends of which are so formed as to furnish support to the lower cross-piece, *b*,

which is a smooth, round shaft. The upper ends of the sides, *a*, *a*, are connected by two short pieces of chain with the cable, by which the whole is suspended. The upper cross-piece, *b*, is a spreader of wood, protected on the outside by a bar or plate of iron. The frame moves in the shaft between guide-rods, *c*, *c*, which are embraced by flanges, *d*, *d*, on the sides of the frame. The body of the skip, when in an upright position, is supported by the lower cross-piece, *b*, to which it is attached by means of boxes, *e*, *e*, and on which it may turn freely when it arrives at the dump. A wheel, *W*, made with a broad face and deep flange, is attached to each side of the skip, and, moving in the space between the guide-rod, *C*, and the shaft-timber, *F*, they hold the skip in an upright position in the shaft, but on reaching the dump the wheels enter the groove *G*, allowing the top of the skip to fall forward while the bottom is raised in the frame, assuming the position shown in the left-hand figure. If the frame be raised still further the skip goes on in an inverted position, the wheels bearing upon the surface indicated by the line *i i*, but on being lowered again below the level of the dump, the skip resumes its upright position without any aid, and continues on its way down the shaft.

Water is raised, by the same skip, from the sump at the bottom of the shaft, as no pump has yet been provided. In order to discharge the rock and water at different dumps, a switch, *H*, is provided, which may be fixed in the position shown in the left-hand figure, or moved, by means of a rod, *h*, into the position indicated by dotted lines. In the former case the wheels of the skip enter the groove *G*, at the lower dump; while in the latter case they pass upward to the groove *G′*, at the upper dump.

The surface works of the mine consist of hoisting machinery, commanding both shafts, and a crushing mill containing 22 stamps. These appurtenances are so placed that the power required for their operation is furnished by one engine. Both shafts are covered by spacious shaft-houses, connected by an intermediate building, in which are the smith and carpenter shops, office, and room for selected or smelting ore.

The drawing on Plate XXXII presents a plan of the hoisting works, showing the arrangement of the winding machinery. The stamp mill, not shown in the drawing, is west of the hoisting works and driven by the same power.

The hoisting machinery consists of an engine, of which the cylinder is $15\frac{1}{2}$ inches in diameter by 36 inches stroke, to which steam is supplied by one tubular boiler 14 feet long by 52 inches in diameter. Power is transmitted from the main engine shaft by a pulley and belt (not shown in the drawing) to the stamp mill, while the winding apparatus is operated by a combination of toothed gearing and friction. A section of the winding-spool, showing the method of applying the friction, is shown in Fig. 2 on the same plate. The spool or drum consists of two interior end pieces, *a, a,* of cast iron, circular in form, having a hub at the center and a flange, *c, c,* at the circumference, to which the staves, *b, b,* are bolted, as shown in the drawing. A cast-iron rim, *d, d,* is put on the outside of the spool, to give additional security to the staves and to provide projecting flanges between which the rope may be wound on the spool. Thus constructed, the spool is supported on the spool shaft *E*, and is free to turn in either direction. It is placed between two friction-flanges *F, F,* likewise circular in form and provided at the periphery with a >-shaped groove. The ends of the spool-staves have a corresponding form so that they may fit into the grooves of the flanges. These latter are attached to the spool-shaft, *E*, by a feather, on which they may be moved toward or from the spool. In the former case the flanges, pressing against the ends of the spool, impart to it the motion of the shaft, winding the rope and raising a load from the mine; while in the latter case, the pressure being relieved, the spool is free, and may be reversed for lowering the skip, or may be held firmly by means of the brake-band, *g*. The flanges are pressed against the spool by means of two rods, *h, h.* The ends of the spool-shaft are bored out so that the rods may be placed in the position shown in the drawing, and pressed, when desired, against pieces of iron, *i, i,* which are long enough to bear evenly against the ends of the flange-hubs, *F, F.* These pieces of iron are about $1\frac{1}{2}$ inch thick and pass through slots cut in the shaft, which is 7 inches in diameter; they are kept in place by pins at *j*. By a system of levers, not shown in the drawing, the attendant may, by a single movement, press the rods *h, h,* against the flanges, thus setting the spool in motion, or, with equal facility, relieve the pressure, reversing the motion of the spool, or holding it firmly by means of the brake, *g*.

It will be seen in Fig. 1 that the spool-shaft is furnished with a spur-

Plate XXXII

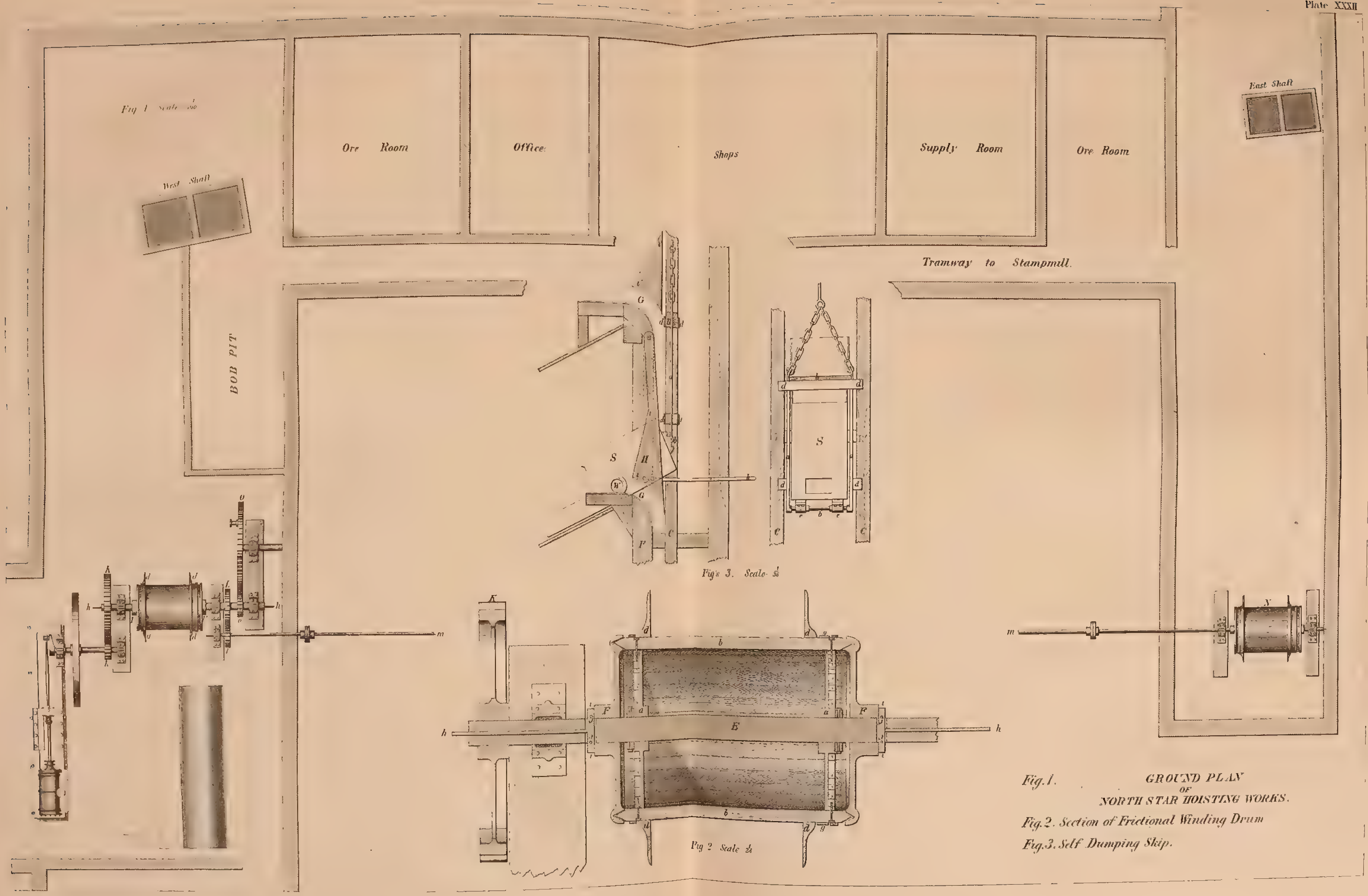


Fig. 1. GROUND PLAN OF NORTH STAR HOISTING WORKS.

Fig. 2. Section of Frictional Winding Drum

Fig. 3. Self Dumping Skip.

wheel, $K$, which is driven by a pinion, $k$, and may be constantly in motion, whether the spool be in revolution or not; by means of gearing $L$, $l$, a line shaft, $m$, transmits power to the spool $N$, which is operated in manner similar to that just described. The pinion $o$, and spur-wheel $O$, are provided for driving the pump, which is not yet placed in the shaft. All the minor appurtenances of the works, such as water-supply, force-pumps, wood-yard, and sheds, and similar conveniences, are quite complete, and the establishment is unsurpassed in Colorado as regards method of arrangement and fitness for its purpose.

The mill in the building adjoining the west shaft-house contains 22 stamps, weighing 550 pounds each, and has a crushing capacity of about 20 tons per day. The average yield of the stamp-rock has been already shown to be about $15 50, coin, per ton. The mine was producing regularly in 1868, but all its yield and more has been absorbed in the costs of the work already described, which is said to have involved the expenditure of more than $100,000. In 1869 the company became much embarrassed financially, and its regular operations were interfered with, although some work was still in progress.

Gardner Lode.—The Gardner lode is nearly parallel to the Illinois and between 300 and 400 feet further north, its outcrop being further down the slope of Quartz Hill, toward Nevada Gulch. Its course is north 85° east, true. Its dip is 75° to the south, and both course and dip, so far as observed by the writer, are very regular. The lode was discovered and partly opened as early as 1860, and has been worked, with some intervals of interruption, from that time to the present. It has been claimed and somewhat developed for a length of over 800 feet, but the most important operations on the vein are in the Clark-Gardner mine, a claim of 200 feet in length. The adjoining claims, both east and west, have been worked to varying depths, not exceeding 200 feet, and have yielded some handsome returns, and as they are partly owned and controlled by the same people who own the Clark-Gardner, there is some hope of a consolidation of interest that will bring at least 800 feet under one management. This is much to be desired for the interest of all owners, as under the present conditions the costs of equipment, opening of ground, and administration of such short claims are so great as to absorb a large share of the proceeds.

The lode, as shown in the Clark-Gardner mine, is a large and regular vein. Its width is seldom less than 3 feet and often 10 or 12. Its walls are smooth and well defined, standing firmly, and involving but comparatively little expense in timbering.

The ore, as in the veins already described, is a mixture of iron and copper pyrites, carrying, however, a considerable proportion of galena and zinc-blende. The valuable mineral appears to be more widely diffused throughout the general filling of the vein than generally observed elsewhere; for while there is usually a compact seam of pyritous ore, it is almost always narrow, and the proportion of high-grade ore, worthy of selection for smelting, is very small. During several months of 1868 not more than 20 tons of first-class ore had been selected from 1,500 or 1,600 tons of ore produced, equal to one in about 80. To compensate for this there is a good degree of uniformity existing in the quality of the milling ore, and occurring, as it does, in a comparatively wide vein, it can be extracted cheaply. The main filling of the vein is a siliceous and feldspathic mixture, but where the vein is wide there is frequently what appears to be an inclosed mass or "horse" of country-rock, granitic in character, though carrying an impregnation of pyrites through it. In the Clark-Gardner mine one-half or two-thirds of all the vein-matter broken is sent to the stamping mill, and yields, on an average, about 6 ounces of crude bullion, or $100 coin per cord, equal to $12 or $14, coin, per ton.

The proportion of first-class ore of the Clark-Gardner mine has already been shown to be small. The sale of this quality to the Smelting Works amounted, in eight months of 1868, to 38 tons, averaging 3½ ounces of fine gold and 11½ ounces of fine silver to the ton.

The Clark-Gardner mine, 200 feet in length, is opened by two shafts, the westernmost having reached a depth of about 360 feet. The ground near the surface was generally unproductive, but at the depth of 80 or 100 feet a good body of pay-ore was encountered, and the mine below that, excepting some poor spots, has been mostly worked out to a depth of 300 feet. The costs of working the ground are comparatively light. Drifting costs from $5 to $10 per foot; sinking, 8 feet by 5, costs $20 per foot; stoping, from $12 to $22 per running fathom. Much of the ground in the lode can be picked down, and comparatively little powder is required. Two men have broken a

fathom of ground in one day. Eight men have supplied the stamping mill with not less than 20 tons of ore per day for two months. The ground is comparatively dry and the costs of timbering are light. The mine is provided with hoisting machinery consisting of a small portable engine that drives a simple winding apparatus by belting, in the common way. The shaft-house is a large stone building, originally designed to contain a stamping mill that is not yet set up. The power provided is sufficient for both hoisting and stamping on a small basis of operations.

Burroughs Lode.—The Burroughs lode is about 400 feet north of the Gardner. Its outcrop is further down the slope of the hill and about 100 to 150 feet above the bed of the Nevada Gulch. Its course is almost exactly parallel to that of the Gardner, being, where observed by the writer, north 85° east, true. Its dip is nearly vertical, or slightly to the south, its average inclination in the Ophir mine being 85°. It is one of the earliest discovered and most developed lodes in the Territory, the main shaft of the Ophir mine having reached, in the summer of 1869, a depth of 630 feet. It is opened for a continuous length of more than 2,000 feet, and worked along that distance to depths varying from 200 to 500 or 600 feet. Unfortunately, it has the practical disadvantage, in common with many other valuable lodes of Colorado, of being subdivided into many different claims, the greater number of which are too short to make independent mines and only serve as obstacles to a consolidated and comprehensive management. One company, the First National, although owning more than 600 feet of the lode, hold it in three or four disconnected portions, between which several other claims intervene, a condition that must greatly increase the cost of operations, if not presenting an effectual barrier to systematic development.

The following list shows the claims on that part of the lode that is distinctly traced and opened by mining work, beginning on the east and proceeding toward the west end. The length of each claim is given and the depth attained by their work at the time when the accompanying section was prepared in 1868, since which little or no important change has been made:

| Name of claim. | Length. | Depth reached. |
|---|---|---|
| W. H. Cushman | 267 | 300 |
| Burroughs Gold Mining Company | 155 | 220 |
| Lacrosse | 50 | *a* 178 |
| Burroughs | 100 | 60 |
| Colorado | 200 | 305 |
| Conlee | 20 | 30 |
| Ophir | 462 | 560 |
| First National | 183 | 265 |
| Gold Hill | 70 | 128 |
| Baltimore and Colorado | 40 | 200 |
| Quartz Hill | 90 | 240 |
| Gold Hill | 20 | |
| First National | 233⅓ | 230 |
| McCabe | 66⅔ | 30 |
| Andrew | 90 | 98 |
| First National | 100 | 60 |
| First National, (one-half interest) | 200 | |

*a* Cut by tunnel.

The section of the lode on Plate XXX, chiefly prepared from one made in 1868 by Mr. A. Buddee, mining engineer, and supplemented by later data in 1869, shows something of the development of these claims.

*Ophir Mine.*—The Ophir is the deepest and most extensively worked of all the mines on the lode. It is situated centrally, as regards the developed portions of the vein, and may properly serve to illustrate the general features of the latter. The Burroughs vein, as shown in the Ophir, resembles in most respects the lodes that have already been described. The country-rock is the same half-gneissic, half-granitic rock already observed. The walls are usually well defined, smooth, and regular, sometimes carrying a thin gouge of clay, sometimes having the seam of ore resting directly upon it without anything intervening. The vein, however, is not wide as compared with other leading veins, varying from 8 or 10 inches to 3 or 4 feet, seldom exceeding the latter.

The vein-matter and the ore, consisting usually of a solid seam of the latter from a few inches to more than a foot in thickness, and associated with a belt of siliceous and feldspathic material highly charged with pyrites, present the same general features in mode of occurrence and distribution that

have been already noted in connection with the other lodes, but the pyritous ore is more exclusively iron rather than copper pyrites; in fact, the small proportion of the latter, at least in the Ophir, is very marked, and the iron pyrites is not only gold-bearing but the Ophir ore carries more silver than is generally associated with the ores of the district similar to these in other respects, the average assay of the first-class ores sold at the Smelting Works showing about 6 ounces of fine gold and 12 ounces of fine silver to the ton. The ground is generally hard, requiring the aid of powder for its removal. Very little of it can be picked down. The mine is opened by means of two shafts, one at 125 feet from the eastern boundary of the property, the other about 60 feet further west. Both of these shafts have reached a depth of about 600 feet. The upper part of the mine was not worked by the present owners and little or nothing is known now of the distribution of ore in the ground taken out; a considerable portion of the mine was poor and is left standing, but nearly all above the 467-foot level is regarded as exhausted of its valuable contents. The earlier owners worked out what they found without much attempt at regular methods, and the first level driven as a preparation for back-stoping was carried forward by the present management at a depth of 467 feet. Sixty feet below that another level was driven nearly the entire length of the property and stoping carried on above it, while the east shaft was sunk with the view of opening another level below in advance of the needs of the mill.

The two shafts are well timbered up and the eastern one is divided into two compartments, one of which is devoted to hoisting, the other to the pump and ladder-way. The pump, which is in two lifts, the lower one being at 467 feet deep, has 8-inch plungers, but the column is a 6-inch pipe, chosen of this diameter to save freight. The water is raised from the bottom to the pump-cistern in buckets; the quantity is comparatively slight; although this mine is the deepest on the lode, the pump seldom runs more than two hours per day.

Hoisting is done in both shafts by iron buckets that are operated in the manner already described as common in the Territory, by means of belting and a friction-brake. The engine for driving the pump and operating the winding apparatus is at the east shaft, and has a 9-inch cylinder. There is

one 14-foot boiler to supply steam. From the main engine-shaft the power is transmitted by a belt to a line-shaft, 60 or 70 feet long, by means of which both winding spools are driven and from which another belt communicates power to the pumping gear.

The rock, when brought from the mine to the surface, is first assorted, selecting the first-class ore for smelting, and separating the waste-rock, that is thrown away, from the low-grade ore, that is sent to the stamps.

The company have a 24-stamp mill, which is situated in the valley directly below the shaft-house, so that a gravity tram-road, a few hundred feet in length, is laid on the hill-side, by which means the ore is conducted in cars from the shaft-house to the mill, the descending loaded car bringing the light one up by its greater weight. The 24 stamps, weighing about 500 pounds each, have an average capacity of 16 to 18 tons per day. The yield of the rock, which will be stated with more detail in a following paragraph, is about six ounces of crude bullion to the cord, equal to $13 or $14, in coin, per ton. In addition to this is the product derived from the tailings, which, as may be seen further on, is considerable. The treatment of tailings will be more fully described after discussing more particularly the general features of the milling process.

The superintendent of this mine, Colonel George E. Randolph, deserves much credit for the systematic and careful method of account-keeping introduced by him. The data furnished here from his books, concerning the operations of the company, are especially valuable, because so little attention is generally paid in Colorado to acquiring and preserving the statistics of costs in the various departments of mining and milling; or to recording such results, obtained from month to month in the progress of the work, as may enable one to form an intelligent judgment of the future by an accurate knowledge of the past. Colonel Randolph took charge of the work in April, 1868. The following statement shows the number of fathoms stoped, the quantity and class of the ore produced, and the costs of mining and milling the same, during the succeeding five months:

| Month. | Fathoms stoped. | Tons of ore mined. | | Tons crushed in own mill. | Cost of mining. | Cost of milling. | Total cost per ton. |
|---|---|---|---|---|---|---|---|
| | | 1st class. | 2d class. | | | | |
| April . . . . . . | 46½ | 8 | 366 | - - | $12 06 | | |
| May . . . . . . . . | 61 | 15 | 430 | 180 | 16 80 | $4 62 | $21 42 |
| June . . . . . . . . | 71⅔ | 6 | 586 | 296 | 12 10 | 4 26 | 16 36 |
| July . . . . . . . . | 82 8/10 | 4½ | 594 | 379 | 11 42 | 2 85 | 14 27 |
| August . . . . . . | 53 | 12 | 416 | 455 | 13 79 | 3 65 | 17 44 |

The fluctuation in the cost of both mining and milling is due to a variety of circumstances, such as the variable amount expended on ordinary repairs in any given month, and the quantity of rock produced or milled during that month.

Thus, in the months of July and August, the costs of milling were less than in the foregoing, because the expenditures for repairs were not so great during those months while the capacity was enlarged by increasing the speed of the stamps and the number of days of running, thus diminishing somewhat the costs per ton.

The first-class ore, sold at the Smelting Works, netted the mine, in the month of May, $93; in July, $98; and in August, $104 per ton, in currency. The yield of the stamp-rock, including that treated in the company's mill and in custom mills, was, in May, $24 50; in June, $15; in July, $12; and in August, $19 per ton, in currency. The total receipts from ores and sale of tailings, and expenditures of all sorts, during the four months referred to, were as follows:

| Month. | Receipts. | Expenditures. |
|---|---|---|
| May . . . . . . . . . . . . . . | $16,491 | $11,731 12 |
| June . . . . . . . . . . . . . . | 8,766 | 10,306 48 |
| July . . . . . . . . . . . . . . | 8,310 | 9,883 36 |
| August . . . . . . . . . . . . | 12,000 | 8,798 62 |
| Total for four months . . . . . | 45,567 | 40,719 58 |

The proportion of first-class, or smelting, ore to the second-class, or stamp-rock, appears from the accounts to be about one in fifty.

Thus we have in—

| | | |
|---|---|---|
| April | 8 in 374 | or 1 in 46 |
| May | 15 in 445 | or 1 in 30 |
| June | 6 in 592 | or 1 in 97 |
| July | 4. 5 in 598. 5 | or 1 in 133 |
| August | 12 in 428 | or 1 in 35⅔ |
| Or, for the five months | 45.5 in 2,437.5 | or 1 in 53.6 |

This statement shows that the great bulk of the ore produced by the class of veins represented by the Burroughs is of the low-grade, or stamping rock. The proportion of the two classes above given differs considerably from the general estimate of those who do not keep careful accounts, but, so far as the data furnished by this mine and others, where the relative quantities of the two classes of ore are accurately noted, afford any basis for judgment, the proportion of first-class to second-class ore is very small.

The relation existing between the amount of ground mined and the quantity of stamp-rock produced is indicated by the following figures:

| Month. | Fathoms of ground stoped. | Tons of stamp rock produced. | Tons per fathom. |
|---|---|---|---|
| April | 46.5 | 366 | 7.87 |
| May | 61. | 430 | 8.15 |
| June | 71.66 | 586 | 8.17 |
| July | 82.8 | 594 | 7.17 |
| August | 53. | 416 | 7.83 |
| Or an average of | .... | .... | 7.60 |

The fathom paid for in stoping is the running or superficial fathom; that is, six feet measured on the length and the dip of the vein, but varying in width according to the thickness of the vein. Estimating the average width of the stope at little more than three feet, the weight of the solid fathom

would be ten tons, from which, as we have just seen, seven and six-tenths tons of stamp rock are obtained, or about three-fourths of the ground broken. According to this, a fathom of stoping ground produces a cord of stamp-rock, which yields, on an average, six ounces of crude bullion, worth about $100 in coin. The price paid for stoping varies very much, according to the character of the ground. It is sometimes as low as $25, and sometimes more than $50 per fathom. Drifting costs from $12 to $20 per foot. Sinking the shaft, 7 feet wide by 14 feet long, at the date of the writer's visit in 1868, cost $52 50 per foot, the miners furnishing their own supplies.

The foregoing notes concerning the operations of this mine were obtained in the latter part of 1868. Shortly thereafter the company became embarrassed financially, and, when visited in 1869, but little work was in progress. A few miners were at work on their own account.

*First National.*—There are several claims on the Burroughs that have been worked to considerable depths, but, during the past year or two, their development has not been very vigorously prosecuted. The Gilpin was steadily worked for a long time, but, in the summer of 1869, little or nothing was in progress on that claim. The First National Company, owning several disconnected claims on the lode, resumed active operations, in 1869, on that which adjoins the Ophir on the west, and have since been steadily engaged in its development. Their shaft, on this claim, has reached a depth of nearly 500 feet. Stoping has been in progress, during the past winter, between the 400-foot and 470-foot levels, furnishing ores that yield an average of $10 50, coin, per ton. A careful system of account keeping has been inaugurated in this mine, and the following statements, setting forth some of the results of their operations, will be found interesting, as throwing light on the relations existing between cost of production and yield of the ore. It will be seen that the former exceeds the latter, and the experience of this mine is one illustration of the disadvantage under which a short claim is worked on a vein like the Burroughs, a fair representative of the Colorado gold-bearing lodes. The vein is narrow, the average value of the ore is low, and the pay is not uniformly distributed. A vein of this character needs all the advantages that may be derived from economical and systematic methods of work. Here, however, is a claim, 183 feet in length, working through a shaft nearly 500 feet deep, the cost of sinking

which is 10 per cent. of all the expenses of the company. As the mine has no connection with its neighbors, the shaft can only aid in the development of a small part of the ground for which it would be sufficient if the claim were longer. The cost of hoisting works, the consumption of fuel, labor of the engineers and some other men, the cost of superintendence and other management of the company's affairs, are nearly or quite as much as they would be if the production of the mine were ten-fold greater. Thus the costs per ton are much increased, and ore, rich enough to afford a profit under favorable circumstances, is produced at a loss under existing conditions.

This is true of many of the mines in Colorado. Some of the best lodes, apparently possessing all the necessary qualities for profitable working, under one comprehensive and economical management, are divided into a multitude of short claims, worked independently of each other, at great expense, and losing their possible profits for the lack of consolidation.

The following statement shows the operations of the mine, in detail, for five weeks, from October 9 to November 13, 1869:

| Week ending— | Tons mined. | Ordinary expenses per ton. | Special expenses per ton. | Total mining expenses per ton. | Tons crushed. | Cost of crushing and hauling (Custom mill). | Total cost per ton. | Yield per ton. |
|---|---|---|---|---|---|---|---|---|
| October 16 - | 87 | $6 96 | $1 71 | $8 68 | 56 | $5 38 | $14 06 | $16 43 |
| 23 - | 60½ | 10 17 | 1 80 | 11 97 | 72 | 5 38 | 17 35 | 10 29 |
| 30 - | 77 | 7 76 | 1 82 | 9 59 | 74 | 5 38 | 14 97 | 12 01 |
| November 6 - | 67 | 8 68 | 0 35 | 9 03 | 76 | 5 38 | 14 41 | 11 79 |
| 13 - | 117½ | 4 97 | 1 93 | 6 90 | - | 4 45 | 11 35 | |

All expenses are included in the foregoing; among special costs is included the sinking of the shaft.

The following is a summary of operations from October 9, 1869, to January 1, 1870, including the foregoing:

Number of tons of stamp-rock raised and milled.................... 850

Average assay value in coin—gold, $25 13; silver, $1 94—total.... $27 07

Number tons smelters' ore raised and sold, (1 in 65,)............... 13.27

| | |
|---|---|
| Average assay value in coin—gold, $131 21; silver, $16 22—total.. | $147 43 |
| Total tons raised | 863.27 |
| Average assay value, coin | $28 92 |
| Average yield, per ton, of milling ore, in currency | 12 68 |
| Average yield, per ton, of smelting ore, in currency | 110 07 |
| Average yield, per ton, of all ore, in currency | 14 17 |
| Average cost, per ton, for ordinary expenses of mining and milling, | 13 59 |
| Average cost, per ton, for special expenses | 2 08 |
| Total average cost, per ton, in currency | 15 67 |

Counting gold at 20 per cent. premium, the average percentage obtained of the value of the low-grade ore was 39 per cent. by milling, and 62 per cent. of the value of first-class ore, obtained by sale to the smelters.

On the same slope of Quartz Hill with the Burroughs, but from half a mile to a mile further west of the principal developments on that lode, and higher up the valley, is another group of mines opened upon ledges that from their course, dip, and relative position seem to belong to the same class as the Burroughs, Gardner, Illinois, and their associated veins, but which present a marked difference in the character of their ores; carrying a much larger proportion of argentiferous galena, zincblende and sulphurets of silver. Assays of the ore frequently show a very high value in the last named metal. Prominent among these are the California, Indiana or Hidden Treasure, Flack, Mercer County, Forks, American Flag, and others. The Mercer County lies east of and in line with the Flack, on what is understood to be the same vein, but the mines are separated by a dry, shallow ravine, which crosses their course. The California and the Indiana bear a similar relation to each other, the two names applying to different parts of one vein, the last named lying west of the ravine, just referred to, and the California lying east of it. The course of the California, continued still further east, shows it to be very nearly in line and probably identical with the Gardner lode, already described. The Forks is between the Flack and the California, having, apparently, a course considerably north of east, and, consequently, intersecting both, if all three are continuous and regular. It is worked actively to a depth of over 300 feet, and

yields very good ore. The American Flag, still further north, not far above the bed of the stream, has also been worked to a depth of several hundred feet and gives indications of much value.

FLACK.—A more minute description of the Flack mine, on the Flack lode, and of the claim until lately known as the Stalker and Stanley, on the California lode, will suffice to represent the general character of this group of veins. The Flack was one of the early discoveries of the district and was worked in 1862. The top quartz is said to have yielded a good deal of money, but detailed records of the product are not in the possession of the writer. At a depth of 60 feet the crevice was small and poor and continued so for 100 or 125 feet further, when a good pay-seam was found. Difficulties among the owners led to a subsequent suspension of work, which was only resumed again in June of 1868. Two shafts are being carried down for permanent work, with the intention of opening ground by successive levels and stoping overhand. One of these had reached a depth of 400 feet in 1869. Drifting and stoping were in progress in the neighborhood of both shafts. The vein is shown by these developments to be narrow, varying from three or four inches to two feet. The walls are of gneiss, sometimes passing into granite, and, where broken, frequently show lines of bedding or structure dipping eastward. The walls are generally very well defined and smooth and show evidences of movement in the beautifully polished and striated surfaces that are formed on the ore-seam where in contact with one or the other wall. Sometimes there is a distinctly marked selvage of clay between the wall and the harder filling of the vein. The vein-matter is chiefly quartz; where associated with pay it is of a softened or sometimes friable character, mixed with some feldspar; where poor, it is harder, sometimes forming a granulitic mixture of quartz and feldspar. This is generally, not only in this but in other veins of the district, the character of the "cap" or barren ground of the lode. The "cap," a term usually employed to express the impoverished condition of the vein, may be due either to the pinching together of the walls of the fissure, or, where the latter maintain their regular distance apart from each other, to the filling of the vein with barren rock, usually resembling granulite or the granite of the country. Thus in the east shaft of the Flack, which passes through a hundred feet or more of "cap," the walls were observed to be two feet or more

apart; on the south wall there seemed to be a fissure by itself, only an inch or two wide, and filled with a soft clayey and siliceous material, next to which was a belt of barren rock that might be described as a granulite, or a granite poor in mica; and north of that, next the north wall of the vein, another and wider belt of true vein-matter. Bunches of the latter may be found in places scattered through the "cap." This condition of things may suggest the idea that these veins were originally formed or filled by dikes of granite or granulite, and that by a subsequent enlargement or widening of the fissure the siliceous and metal-bearing vein-matter was introduced by other processes of infiltration or segregation by which it is generally believed that fissure veins have been filled. The ore-seams and their gangue are frequently, indeed generally, arranged in layer or banded form, with a considerable degree of parallelism and with the drusy character of true vein filling. Movement in the walls would naturally occasion the irregularity in the width of the crevice, and the shattering or fracturing of the original dike material would afford opportunity for the intermixture of the newer vein-matter with the old. Movement in the case of the vein now under consideration is clearly evidenced by the "slickensides," or polished surfaces, already referred to.

It has already been stated that, where ore-bearing, this vein carries a considerable proportion of zincblende and galena. These occur sometimes intimately mixed with the iron and copper pyrites, while in some places they are arranged in distinctly separated seams. In the stope east of the east shaft the vein was 12 or 15 inches wide; on the north wall was a very thin selvage of soft, clayey material, followed by a seam of dark-colored blende and galena, two or three inches wide, somewhat mixed with and succeeded by a seam of greenish, siliceous, and perhaps talcose vein-matter, carrying finely-divided iron pyrites; then a seam of solid iron pyrites, two or three inches thick; the remainder of the vein was a quartzose material carrying finely-distributed pyrites suitable for crushing in the stamp mills. In this place there was but little copper present, though elsewhere copper pyrites is sometimes largely represented, and argentiferous gray copper occurs sometimes with the galena and the zincblende.

Concerning the yield of the rock, on a large working scale, the writer could obtain but little positive information. The stamp-rock, it is said, yields

about one ounce of retorted amalgam per ton; this, however, contains sufficient silver to reduce its value considerably below that of the bullion produced by those mines whose ores are poor in silver. The average value of the ounce of bullion obtained from the Flack ores is stated at $13, in coin.

The higher class of ores, carrying considerable silver and combined with lead, zinc, and copper, are reserved for smelting. One lot of nine tons, sold to Professor Hill early in 1869, gave, by assay, seven ounces of fine gold and sixty-eight ounces of fine silver per ton.

The total production of the mine, since the present management began operations, could not be ascertained. The mine is provided with a small portable engine, of which the cylinder is 9 inches in diameter, that is placed between the two working shafts, but near the western one, commanding both for hoisting. The winding apparatus is operated in the manner already described, by means of belting.

California.—The California lode has of late attracted more attention than any of its neighbors, having, within a year or little more, gained a great reputation by reason of the abundance and richness of its ores. It was discovered several years since, and has been worked more or less since 1864. It is nearly parallel to the Flack, and 300 or 400 feet north of that lode. It is traced for many hundred feet in length. West of the dry gulch, near the Stalker and Stanley claim, the lode is known as the Indiana, and has been sunk upon in various places along its course. The only parties working on that part of the lode in 1869 were three men, who had reached a depth of 150 feet, and were taking out good ore of both classes—that is, for smelting and milling. East of the gulch is the principal claim on the lode, formerly known as that of Stalker and Stanley, but the ownership has lately changed hands. This claim is 300 feet long. East of it the lode has been traced and somewhat prospected for a distance of some hundreds of feet, and apparently continues in its course until it merges into or becomes identical with the Gardner. This is not fully established as a fact, and is doubted by some; but it seems quite probable from present developments.

The Stalker and Stanley claim has been worked to a depth of 475 feet. The main shaft, 50 feet east of the west boundary, had reached that depth in August, 1869, while the east shaft, 130 feet east of the last named, was down

300 feet. Between the two shafts, considerable stoping had been done, but the ground was whole below the 300-foot level.

From the developments thus made the lode appears to possess the characteristics of a well-defined fissure vein. Its course is north 85° east. The dip is slightly to the south, about 85° from the horizon. The walls are smooth and very regular. They are from two to six feet apart, and, in the stopes visited at the time referred to, the whole space was filled with pay-ground. The gangue is a quartzose material, generally resembling that already described as the characteristic filling of the veins of this region. The ore is chiefly iron and copper pyrites, carrying, in bunches or pockets, considerable quantities of galena and zincblende, particularly the last named. There is commonly a seam of first-class ore, associated with a wider belt of milling ore.

During the past year the ground has been unusually productive. According to the statements of the proprietors, not more than one-eighth of all the rock broken in the mine is thrown away as poor; while one ton of ore in ten is said to be fit for smelting. The value of the milling rock is said to be very high, yielding an average of 12 ounces of amalgam to the cord, the ounce being worth about or little more than $13, in coin. According to this, the milling ore yields about $21 per ton, in coin. The average contents, by assay of over 400 tons of smelting ore sold at the Smelting Works, was nearly 3 ounces of fine gold and 18 ounces of fine silver per ton.

The mine has not always been in such good fortune. When first opened the surface quartz was taken out about 40 feet deep, and was worked with profit. The shaft then encountered poor ground, which it passed through for 180 feet. It has since been shown that there was excellent ground only a few feet from the shaft, which remained undiscovered because no drift was run toward it from the shaft. At the depth of 180 feet the shaft reached ore-bearing ground, that yielded about 7 ounces to the cord, or $12 to $13 per ton. The yield has greatly improved since opening the stopes between the shafts.

In August, 1869, there were 24 men employed at the mine, 16 of whom were stoping. With this force about 30 tons of ore per day were mined and raised. Sinking cost $15 to $20 per foot; stoping $12 or $18 per fathom.

A detailed statement of costs could not be obtained; but the mine is said to have yielded a net profit of $40,000 during the summer.

The mine is provided with a small hoisting engine. Both rock and water are raised in buckets. Four hours per day are required for the engine to raise the water from the mine. From reliable sources the yield of this mine to its owners, from January 1 to August 1, 1870, appears to have been about $75,000, including the product of the first-class ore. This latter amounted to 409 tons, of which the average price paid in currency by the smelters to the mine was $41 90 per ton.

Gunnell Lode.—North of Quartz Hill, separated from it by Nevada Gulch, and lying between the latter and Eureka Gulch, is Gunnell Hill, which, since mining first begun in Colorado, has been the scene of active work. Its general trend is east and west, and it contains a number of valuable veins, the general course of which is east and west, or between that and northeast and southwest. The most developed of these is the Gunnell lode, that crops out on the northern slope, not far below the crest of the hill, and which has been worked to a depth of about 500 feet, the opened mines covering a length of nearly 1,200 feet. The general features of this lode are said to be much the same as those of veins already described in this chapter; but, as none of the mines were working during the writer's visit to the region, there was no favorable opportunity afforded to go underground. The vein is said to have been one of the most productive of the country in early days, and it possesses, doubtless, as much merit as many of those that are now being wrought; but, owing to various difficulties and hinderances, some of them quite independent of the intrinsic merits of the property, the work of mining on this lode was suspended some time ago, and is not yet resumed. The principal mines on this lode are supplied with hoisting and milling machinery, and the increasing activity attending mining operations in Colorado will be likely to occasion renewed efforts to bring them into successful and profitable operation. On this hill are several other less developed, but very promising, ledges, some of which have been lately opened. Among these is the Fairview, which was first brought into notice in the early summer of 1868. It has since been worked steadily, producing rock of excellent quality, and, it is said, has been

a source of great profit to the owners. Its ore is chiefly iron pyrites, yielding from one to two ounces of crude bullion per ton.

WINNEBAGO LODE.—On the opposite side of Eureka Gulch, and further east, is Casto Hill, the location of an actively-worked and promising mine, belonging to the Barrett Mining Company, and opened on what is known as the Winnebago lode. This lode, nearly parallel to the Gunnell, has about an east and west course, dipping vertically, or somewhat inclined to the south. The Barrett Company own 400 feet and have worked it by means of a single shaft some 300 or 400 feet deep. This shaft has passed through variable ground, having encountered "cap" or barren rock at about 100 feet from the surface, and striking pay-ground again 100 feet deeper. The ground is opened by levels and worked by backstoping. About one-third of the rock broken is said to be good for stamps, and much of the poor rock is selected below ground and left on the stulls. The ore is chiefly iron pyrites with but a small proportion of copper. The presence of free gold is frequently noticed. The present manager treats all his ore by the stamping process, though some experimental lots of first-class ore have been selected for other more exact methods. One such lot of 24 tons gave, by assay, 4 ounces of fine gold and 4 ounces of fine silver to the ton. The whole mass, when stamped, yields on an average 4 ounces, or $64 worth, of crude bullion to the cord, or about $8 50 coin, per ton. The tailings, after leaving the mill, are said to assay 1 ounce or more to the ton, and are reserved for further treatment. The mine is furnished with hoisting power, consisting of an engine, the cylinder of which is 14 inches in diameter, and one boiler of adequate capacity. The winding apparatus is the common spool, driven by belting and controlled by a friction-brake. The water is raised in a barrel by this means.

The machinery is set up at the mouth of the shaft and drives a fan-blower for ventilation, as there is but one shaft. A 20-stamp mill is set up in a wing of the same building and driven by the power just described. The stamps weigh 500 pounds each and drop 18 inches 28 times per minute. They crush about 2 cords, or 15 tons, per day. Milling operations commenced in July, 1868, and are said to have been conducted with profit. The convenience of the mill to the mine, and the economical arrangement of the whole, affords some advantages for working at a low cost.

COALEY AND GILPIN LODES.—Although the mineral veins of Gilpin County are chiefly valuable for their gold, there are some, as has been already shown, that carry a considerable proportion of silver. In addition to these there are a few that are only valuable for silver and which possess no gold at all, or so little that it is practically unimportant. The development of these silver veins has not progressed very far, but within a year past they have attracted increased attention and are now of growing importance. The Coaley and Gilpin lodes are among the more recent and valuable discoveries of this class of veins. They are situated in Slaughter House Gulch, a ravine on the north side of Clear Creek, a half mile or more below Black Hawk; they were opened late in 1868.

The Gilpin apparently crosses the ravine with a northeast and southwest course, dipping almost vertically. It is opened by a tunnel on the west side of the gulch, about 200 feet in length. The Coaley crops out about 60 or 70 feet south of the mouth of the Gilpin tunnel. Its course is nearly east and west and its dip is to the north at about 30° from the horizon. The two veins, therefore, intersect each other. The work done upon them thus far is not sufficient to determine positively whether they are independent veins or one of them a branch of the other. The depth reached in August, 1869, did not exceed 40 feet.

The inclosing rock is of the same gneissic or granitic character which prevails in this district. The walls of the vein, where visible, especially the north wall of the Coaley, are pretty well defined; the crevice is not large in either vein. The gangue is chiefly quartz; the ore consists of galena and zincblende, both apparently argentiferous, a little copper and iron pyrites, argentiferous sulphurets, and native silver. The latter, in some selected specimens, is very abundant. Some of the assays of this ore show a very high value in silver but no gold. Seventy-three tons of this ore, sold for smelting, contained, on the average, 215 ounces of fine silver per ton.

## SECTION II.

### TREATMENT OF THE ORES.

It has already been said that the ore produced by the gold-bearing veins of Colorado is generally divided into two classes that are treated by different methods for the extraction of their valuable contents. The first-class, which is but a small proportion of the whole, consists of a selected portion of rich mineral that occurs in the vein in a somewhat concentrated form, or mixed with comparatively little gangue. The chemical nature of the minerals with which the gold and silver are combined, or intimately associated, is such that nicely-adapted and somewhat costly methods of metallurgical treatment are required in order to extract a reasonably high percentage of the value contained, and the ore selected for such treatment must consequently be rich enough to leave a profit after paying the costs of the operation. The second-class, comprising the bulk of the ore produced, is vein-rock or quartz, throughout the mass of which the gold-bearing mineral is sparsely distributed, and of which the low average value demands a cheaper method of extraction. The valuable mineral of the second-class ore does not appear to differ essentially in chemical composition from that of the first-class, and when treated in the simple manner now in general use, yields a very much lower percentage of its value than does the first-class under more exact methods, but, owing to its meager distribution through the gangue, the value of the whole is so low that the greater percentage that might be extracted by any better methods yet available would not be sufficient to pay the increased costs of working, so that for the present, at least, or until new improvements are made practicable, the miner must needs be content with the cheaper, though less efficient, methods.

The two principal methods now in use in the gold district of Colorado are, for the high-grade or first-class ore, smelting, by which the gold, silver, and copper is obtained in the form of regulus, or crude metal, which is at present sent to Swansea in that form for separation and refining; and, for the second-class ore, crushing by stamps and amalgamating the gold by means of quicksilver. Besides these two methods, some other processes are in use to

a limited extent, or are being introduced, but without having yet come into general favor.

In the following pages the principal methods above referred to will be described with sufficient detail to give an idea of their general character, after which some of the other processes may be briefly noticed. As the great bulk of the ore raised from the mines is treated by crushing and amalgamation, the operations of the stamping mills will be taken up first.

MILLING.—The ore designed for treatment by this method is first reduced to fragments of a suitable size for feeding to the stamps, which is done either by hand or by a stone-breaking machine. Blake's Rock-breaker or Dodge's Crusher are used more generally than other machines for this purpose in Colorado. The rock is then supplied to the stamps.

The general character and method of arrangement of crushing or stamping machinery, as used in Nevada, has been already described in a foregoing chapter. The mills of Colorado are similar, in many respects, to those of Nevada. It will, therefore, be unnecessary to describe in detail all the various parts of machinery that are common to mills of this sort, and a brief notice of some of the characteristic features of those in Colorado will be sufficient here. The drawings on Plate XXXIII illustrate many of the details of construction of a Colorado crushing mill for the treatment of gold-bearing rock. The case illustrated is a battery in the Trust Mill, on Lake Gulch, under the management of Mr. H. B. Brastow. The reference table on the plate will make the drawings intelligible without further explanation.

The Colorado milling machinery has been mostly supplied from Chicago, though the machine shops of other western cities are somewhat represented. The stamps, as a general rule, are heavier, run more slowly, and with greater fall than is usual in the mills of California and Nevada. Some of them weigh 900 pounds each, and although the mills of most recent construction have generally adopted a 500-pound or 600-pound stamp, the average is probably somewhat higher than that at present. Some run with as low a speed as 15 drops per minute; others as high as 40; while the average will probably not exceed 28. The fall is from 12 to 18 inches. The revolving stamp is in general use. The high mortars, having the bottom and sides cast in one piece, so generally used in Nevada and California, are not

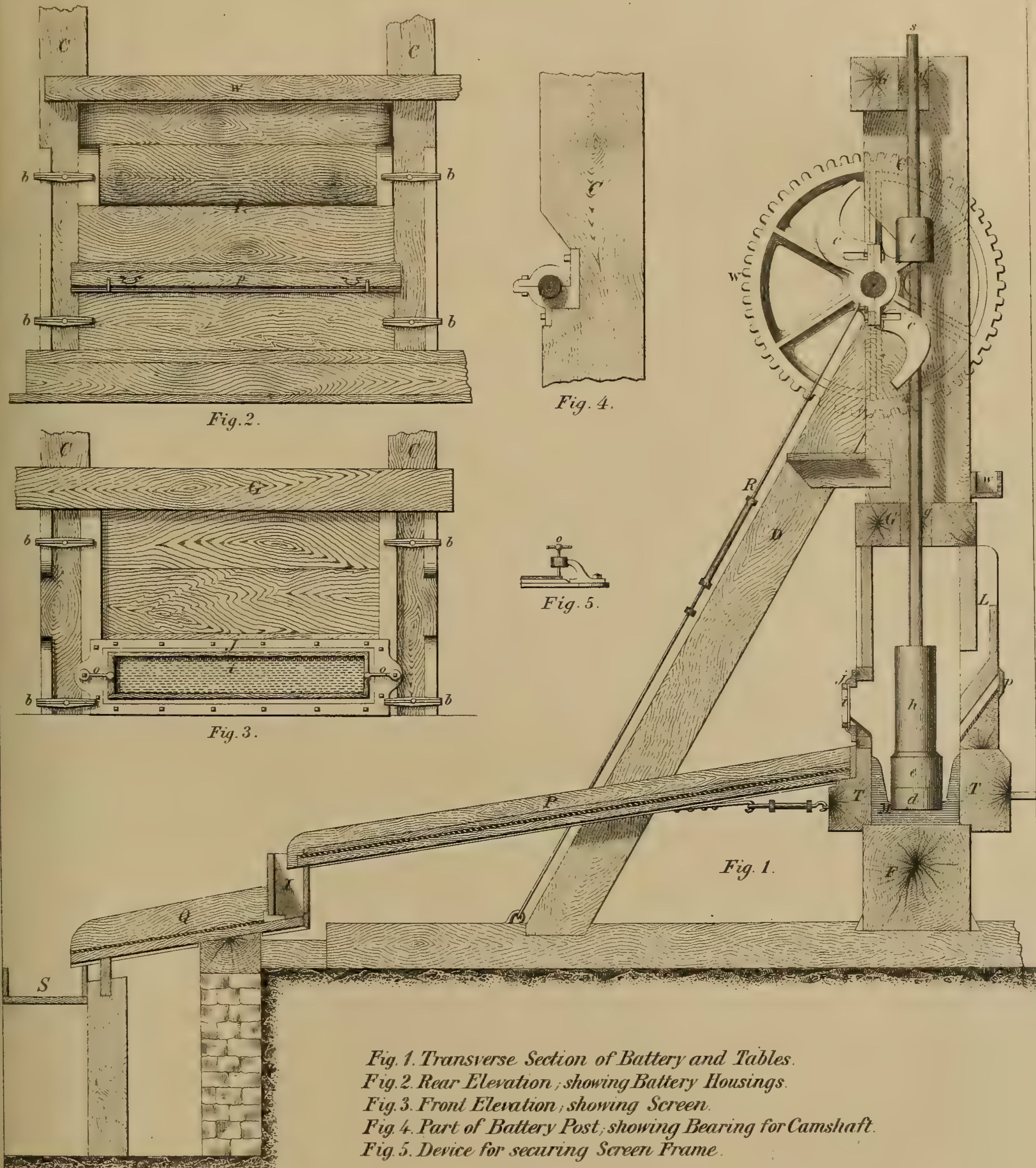

Fig. 2.

Fig. 4.

Fig. 5.

Fig. 3.

Fig. 1.

*Fig. 1. Transverse Section of Battery and Tables.*
*Fig. 2. Rear Elevation; showing Battery Housings.*
*Fig. 3. Front Elevation; showing Screen.*
*Fig. 4. Part of Battery Post; showing Bearing for Camshaft.*
*Fig. 5. Device for securing Screen Frame.*

F. *Foundation Timber or Mortar Block*
T. *Longitudinal Timbers.*
C. *Battery Posts.*
G. *Tie Timbers.*
D. *Brace.*
R. *Rod.*
M. *Mortar.*
L. *Feed Aperture.*
i. *Screen*
j. *Screen Frame.*
o. *Screw to secure Screen Frame.*
b. *Buttons to secure Housings.*
s. *Stamp Stem or Lifter.*

t. *Tappet.*
h. *Stamphead.*
e. *Shoe.*
d. *Die.*
c. *Cam.*
g. *Guides.*
w. *Watertrough.*
p. *Amalgamating Plates in Battery.*
P. *Table covered with Amalgamated Copper plates.*
I. *Trough leading to Table.*
Q. *Short Table, covered with Copperplate, leading to*
S. *Sluice.*
W. *Spur Wheel on Cam Shaft.*

found in Colorado. The mortar in common use in this Territory is a simple iron trough, four or five feet long, twelve or fourteen inches wide, and nine inches deep, cast with a solid bottom, which should be nine or ten inches thick, but is often less. It is laid on wooden foundations, made, sometimes, like those already described, of sound timbers, set vertically, their ends resting on firm ground; or, more commonly, on a long, horizontal mortar-block, that rests on other cross-timbers, placed horizontally. The bottom of the mortar on the inside contains recesses into which the dies sink and are secured. The latter usually have flat octagonal bases with a wearing surface rising above it of cylindrical form, corresponding to that of the shoe, usually 8 inches in diameter. (See Fig. 1, Plate XX.) The battery-work above the mortar is all of wood. The housings are of plank, the front and back being so made as to be readily taken down, giving access to the inside of the battery. The screens are of Russia sheet-iron, 9 or 10 inches wide and as long as the battery, fixed in a frame that can be secured in front of the battery by keys fitting in the grooves, or other simple contrivances, one of which is shown in the drawing. The discharge is usually only in front. The screens are punched with very fine slits about one-third of an inch long and the same distance apart. The battery usually contains four or five stamps. These in general features resemble the California stamps, consisting of a stem, head, shoe, and tappet or collar, by means of which the cam raises the stamp. The tappet in Colorado is usually adjusted to its place on the stem by turning it on a screw-thread, cut for the purpose, and is fixed by means of a key or wedge that is driven into a key-seat cut in the tappet and stem. In some mills the stamp-stems are made with a slight taper in the part to which the tappet is to be attached, and the latter, having a corresponding form, being driven on to the stem, holds its place by friction. Such is the form of the tappet shown in the drawing on Plate XXXIII. The California tappet, described in a foregoing chapter, and illustrated in Fig. 4, Plate XX, which is deemed by those mill-men who have used it as superior to any other, has not yet come into general use in Colorado.

The stamp mills of Gilpin County are generally operated by steam, though some that are favorably situated on the water-courses obtain power from that source. Many mills, however, are located on the mine supplying the ore, the

stamping machinery being under the same roof with the hoisting or pumping works and operated by the same power, which, where practicable, affords a great saving in cost and care of machinery and in the labor of handling the rock. The power is generally transmitted from the engine by belt to a counter-shaft, from which the stamps are usually run by gearing. The convenient method, in use in Nevada and California, of running each battery or two batteries by a belt, so that by applying or withdrawing a tightener any battery may be set in motion or stopped independently of the other batteries, is not here in use. A cam-shaft in Colorado is generally made long enough for all the stamps in the mill, or if the mill be a large one, for twenty or more stamps, the stoppage of one battery involving the delay of all the others run by the same shaft. The cam-shaft is generally driven by a geared wheel, though the shaft carrying the driving pinion is commonly operated by belting.

Wet-crushing is used altogether in the milling of gold ores in Colorado. Water is introduced into each battery by a number of small pipes that draw their supply from a trough *w*, shown in the drawing. The quantity must be sufficient to carry out the material as soon as it is reduced to the necessary degree of fineness, this being determined by the mesh of the screen in front of the battery through which it is discharged. Amalgamation is performed in the battery, in which a supply of quicksilver is maintained for the purpose of taking up the gold as soon as liberated by the crushing process. The quicksilver is usually introduced into the batteries in small quantities from time to time, as may be necessary, according to the richness of the ore and the rapidity with which the amalgam is formed. The appearance of the latter, as it issues from the battery, is one indication, to the attendant, of the quantity of quicksilver present. Hard, dry, and dense particles of amalgam show the lack of a sufficient quantity, while from the degree of fluidity of the particles the presence of a sufficient quantity, or of a surplus, of quicksilver may be inferred. The ends of the batteries are lined with amalgamated copper-plates, while another plate of the same kind, about 10 or 12 inches wide and as long as the inside of the battery, is so fixed in a frame that it may be introduced and secured in an inclined position behind the stamps. A similar plate, though narrower, is generally used on the front or discharge side of the battery. A portion of the amalgam, as it is formed in the battery and

splashed against these plates, adheres to the amalgamated surfaces and is retained upon them. The batteries and plates are cleaned up at stated intervals, differing in length in various mills, in some once each day, in others only once in three or four days, and the amalgam that has collected in the battery, about the stamps and on the plates, is removed. From one-half to three-fourths of the total product is obtained from this source, while the remainder comes from the other appliances used outside the battery for the purpose of catching the amalgam. These consist mainly of aprons or tables, covered with amalgamated copper-plates and constructed in various ways. Usually the stream of water flowing from the batteries and carrying with it the finely crushed ore, some of the amalgam and quicksilver, with much still unamalgamated gold, passes over an inclined plane or table, 5 or 6 feet wide and from 6 to 12 feet long, and covered with copper-plate. These tables are placed in front of the batteries, so that the stream passes directly over them. Generally one table of the dimensions above given is provided for each battery of stamps, though in some mills there is but one table for two batteries. The table should be fixed at such an inclination that the stream of water may run down readily over its surface, carrying with it the charge of crushed rock, but with not so great a velocity as to wash away the amalgam or prevent its adherence to the plate. This inclination is usually about one inch of fall to six inches or one foot of length, but is variously determined by different millmen, depending chiefly on the quantity of water used, and other conditions, as experience may direct. In some mills the material first passes over a short copper-plated apron, only 20 or 30 inches long and thence to shaking-tables, that instead of being fixed are suspended at about the same inclination as the stationary table, and to which a slight forward and backward movement is given, accompanied by a sudden shock or percussion. The surface of the table, instead of being smooth, has a number of riffles or grooves, at right angles to the long side of the table or the line of motion, which serve to contain quicksilver and afford increased opportunities for contact with the ore and amalgamation of the gold. Leaving these machines the stream continues to flow on, in some cases immediately out of the mill into tanks or basins where the residue of the material, or "tailings," is deposited; in other cases over a variety of machines provided for the further saving of the gold or the concentration of

the heavier and better portions of the ore and the escaping amalgam. Usually there is a long wooden sluice or canal, the bottom of which is covered with copper in the same manner as the tables just described, or with coarse blankets which catch the pyrites and some amalgam, which being washed off from the blankets and collected, may be treated in grinding pans or sold to other parties for treatment by methods to be noticed further on. The amalgam formed in the batteries and on the tables is cleaned up at intervals varying in length according to the richness of the ore. In some mills the outside plates or those on the inclined tables are cleaned daily, while the batteries are allowed to run three or four days without cleaning. The outside plates are cleaned by carefully scraping off the adhering amalgam, first gently with a knife and finally with a thick piece of hard gum or rubber, which scrapes the surface closely without cutting or scratching it. The plate is then washed with water and prepared for use again by sprinkling quicksilver over it, spreading the same evenly by means of a cloth, thus forming a freshly amalgamated or quicksilver-coated surface.

The plates that are fitted into each battery, or mortar, are cleaned in like manner, and the mortars themselves, the stamps being hung up and the housings sufficiently removed, undergo a similar operation, the shoes, dies, and interior iron-work being carefully scraped with a knife, in order to remove the adhering amalgam. The amalgam, thus collected, contains some impurities, in the form of pyrites, iron, and dirt, which must be removed before retorting. It is usually put into a wedgewood mortar, or other suitable vessel, and stirred or agitated with water, by which means the dirt or lighter portions rise to the surface, and may be floated or washed off into a cistern or other vessel, and collected there for future treatment. The amalgam may then be rendered fluid by the addition of more quicksilver, the impurities brought to the surface by agitation, and skimmed or cleaned by a piece of coarse blanket, to which the particles of dirt and other foreign substances adhere. By repeated operations the amalgam may be obtained in a very clean condition, the skimmings being subsequently cleaned in similar manner. When thus prepared the amalgam is strained through a piece of cloth and forcibly pressed so as to squeeze out as much as possible of the surplus quicksilver. The remainder is then retorted. In most mills small

retorts are used, holding from 100 to 300 ounces of amalgam; though, in some others, retorts of several thousand ounces capacity are employed. The common retort is a conical pot of cast iron, 4 or 5 inches in diameter at top and 6 or 7 inches deep. A lip or flange is formed around the mouth by iron rings, that are shrunk on, the upper surface of which is smoothly ground and fitting to a corresponding surface on the under side of the cover. The latter is put on and secured by clamps and a screw. The top is provided with a curved neck, to which is fitted a long pipe, which, being kept in cold water, serves as a condenser for the vaporized quicksilver. When charged, the retort is heated in a common forge fire, gently at first, and afterward strongly. The bullion obtained is usually from one-fourth to one-third, or rarely one-half, of the original quantity of amalgam, while the quicksilver, after being condensed, is recovered for further use. This crude bullion is worth from $15 to $18 per ounce in coin, sometimes little more or less, but, on an average, $16 50. As all the gold-bearing ores contain some silver, there is always a little of that metal present in the bullion, and in those ores that contain an unusual proportion of silver the value of the ounce of crude bullion is considerably reduced by its presence, as in the case of the Flack and California ore, of which the retorted bullion seldom exceeds $13, in coin, per ounce. In this form the retorted bullion is usually sold by the producers to the bankers at Central City. It is forwarded thence to the Branch Mint at Denver, or to other establishments, where it is melted and run into bars or ingots. In this melting process a portion of the impurity contained in the bullion, consisting of iron, unexpelled quicksilver, dirt, &c., is removed, and the bar of metal produced is of somewhat higher value than the crude bullion. The loss in melting, therefore, varies according to the care with which the amalgam is cleaned before retorting. The value of the melted bar, per ounce, is generally about $18, in coin. Having reached this form, the metal is generally shipped to eastern markets, where it is subjected to further processes of separation and refinement.

The following tabular statement shows the percentage of loss in melting the retorted bullion, produced from several different lodes; the fineness of the bar obtained, the proportions of gold and silver present being expressed in

thousandths; and the coin value, per ounce, of the crude bullion and of the melted bar.

*Statement from the records of Messrs. Warren Hussey & Company, bankers at Central City, Colorado.*

| Date. | Description. | Where from. | Loss per cent. in melting. | Fineness of bar in— | | Coin value per ounce of— | |
|---|---|---|---|---|---|---|---|
| | | | | Gold. | Silver. | Crude bullion. | Bar. |
| October, 1867 | Mill retort | Briggs lode | 2.15 | 808½ | 172 | 16.48 | 16.85 |
| January, 1868 | Mill retort | Briggs lode | 2.71 | 803½ | 186 | 16.31 | 16.76 |
| | Mill retort | Briggs lode | 2.95 | 811½ | 180 | 16.42 | 16.92 |
| | Mill retort | Briggs lode | 3.56 | 816 | 178 | 16.40 | 17.01 |
| December, 1867 | Mill retort | Bobtail mine | 5.26 | 863½ | 128 | 17.00 | 17.92 |
| | Mill retort | Bobtail mine | 3.00 | 849½ | 140 | 17.27 | 17.65 |
| | Mill retort | Bobtail mine | 11.03 | 864½ | 127 | 15.96 | 17.94 |
| | Mill retort | Bobtail mine | 1.46 | 860½ | 133 | 17.61 | 17.87 |
| January, 1868 | Mill retort | Bobtail mine | 4.55 | 866½ | 125 | 17.16 | 17.98 |
| | Mill retort | Bobtail mine | 1.35 | 866½ | 128 | 17.74 | 17.98 |
| | Mill retort | Bobtail mine | 1.16 | 869 | 126 | 17.82 | 18.03 |
| | Mill retort | Bobtail mine | 3.15 | 865 | 125 | 17.38 | 17.95 |
| | Mill retort | Bobtail mine | 4.85 | 866 | 124 | 17.11 | 17.98 |
| August, 1868 | Mill retort | Bates lode | 8.72 | 746 | 241 | 14.29 | 15.66 |
| June, 1868 | Mill retort | Bates-Hunter | 13.10 | 845 | 150 | 15.27 | 17.26 |
| May, 1868 | Mill retort | Burroughs lode | 2.63 | 833½ | 158 | 16.93 | 17.39 |
| | Mill retort | Burroughs lode | 3.11 | 820 | 166 | 16.58 | 17.11 |
| March, 1868 | Mill retort | Illinois lode | 4.19 | 781½ | 211 | 15.96 | 16.34 |
| December, 1867 | Mill retort | Alps lode | 1.73 | 758½ | 225 | 15.61 | 15.89 |
| June, 1868 | Mill retort | Flack | 4.43 | 641 | 348 | 13.03 | 13.66 |
| | Mill retort | Flack | 5.20 | 653½ | 330 | 13.18 | 13.89 |
| | Mill retort | California lode | 12.42 | 721½ | 269 | 13.26 | 15.14 |
| | Mill retort | California lode | 7.20 | 717 | 267 | 14.01 | 15.09 |
| December, 1867 | Mill retort | Tenth Legion, (Empire) | 20.24 | 886 | 90 | 14.65 | 18.33 |
| | Mill retort | Roland, (Empire) | 8.03 | 895 | 78 | 17.10 | 18.50 |
| June, 1868 | Mill retort | Conqueror, (Empire) | 2.87 | 899 | 86 | 18.09 | 18.63 |

Capacity.—The low speed at which the stamps are generally run affords a much smaller working capacity than is common in Nevada and California. The average duty per stamp per day in Colorado, so far as it can be ascertained, is probably less than one ton of rock. In the Black Hawk mill, containing 60 stamps, weighing 850 pounds each, falling 14 inches, 15 times per minute, the average duty is said to be 27 cords per week, or about 30 tons per day, equal to half a ton per head. In other mills, with lighter stamps and greater speed, this duty is increased considerably, but only in few mills amounts to a ton per day. It is said by some that more gold is obtained by slow speed than by high; and it is quite probable that the difference in the

method of occurrence of the gold, and the nature of the minerals with which it is associated, as compared with the gold-bearing quartz of California, may require slower crushing, especially where amalgamation in the battery is relied upon for so large a portion of the product. Nevertheless, lighter stamps, shorter drop, and increased speed are coming more into favor, and experience will doubtless show in time what improvement is possible in this direction.[1] It may also be a question, not yet satisfactorily settled, whether or not there would be greater economy in increasing the duty of the stamps and providing better or more extended facilities for amalgamation outside of the battery, as is the practice in some of the principal mining districts of California.

Costs of Crushing.—Concerning the costs of stamping, the available amount of statistical information is very meagre, because of the very little attention that is generally devoted, in this region, to the classification of such accounts. Many of the mills are placed at the mine, operated by the same power and sharing with the mine the costs of fuel consumed; the ore, in such cases, being delivered from the mouth of the shaft directly to the stamps, without any exact record being kept of the quantity stamped. It is generally estimated that ore can be treated for \$20 per cord in steam mills, while the average price, for custom work, is from \$30 to \$35 per cord. Milling accounts, available to the writer, show that, in the mills to which they refer, the actual costs were somewhat more than \$20 per cord. Thus, in the mill of the Ophir Company, working on the Burroughs lode, the milling costs, for several months of 1868, varied from \$2 85 per ton to \$4 62 per ton, the average, for over 1,300 tons, being \$3 69 per ton. This, allowing seven tons and a half per cord, would make \$27 67. In the mill of the Sensenderfer mine, during the month of August, the costs of milling 30 cords of ore were stated by Mr. George T. Clark, the manager, at \$700, equal to

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[1] In this connection the following comparative experience, related to the writer by the superintendent of the Black Hawk mine, is interesting. The Black Hawk mill has heavy stamps, running 15 drops per minute. The Eagle mill, near by, has lighter stamps, running 30 drops per minute. Some time ago both mills were working on the same ore, the loads being hauled alternately to either mill. The Eagle, with 20 stamps, crushed nearly 15 cords of rock, while the Black Hawk, with the same number, only crushed a little over 7; while the Eagle obtained nearly an ounce more bullion to the cord of ore than the Black Hawk did.

$23 33 per cord, or, converted into tons as above, $3 11 per ton. This does not include anything for hauling from the mine to the mill, which, in the instance last given, was $11 per cord. Mills run by water power are probably able to treat ore for a considerably lower figure, but, as a rule, they are further from the supply of ore, involving not only a greater cost for hauling, but being more liable to interruption; the roads, at certain seasons preventing, or being liable to prevent, the delivery of the rock. The occasional lack of water, and the consequent interference with steady operations, is also a contingency of a water-power mill that tends to increase the costs of working, somewhat, in the long run.

The chief items of expense in steam mills are fuel, labor, and repairs, including in the last term the replacing of shoes, dies, and other wearing parts. Besides these are water, when purchased, quicksilver, and other incidental expenses. Judging from all available data, the consumption of fuel is about equal to one cord of wood for six tons of rock stamped. In the Ophir mill, in 1868, in which the accounts were kept with much care, the quantity of ore crushed, per cord of wood consumed, during June, July, and August, was respectively 4.23, 5.66, and 5.23 tons. According to the tabular statement, on a following page, showing, in detail, the operations of a number of mills, the quantity of ore crushed per cord of wood used, varies from 5 to 15, and appears to average about 6. The price of wood varies from $5 50 to $7 50 per cord. The cost of fuel, for milling, may therefore be placed at about $1 per ton of ore.

The number of men required in a steam mill of ordinary capacity is seldom less than four, and more frequently five. In a mill of 24 stamps there are usually 2 engineers, 2 stamp-feeders, 1 foreman, who may attend to the cleaning up and retorting; in addition to these an ore-passer is needed in some mills, assisting the feeders, wheeling in the rock and sledging the larger pieces, if there be no stone-breaking machine; and a general helper, in front of the batteries, attending to the disposition of the tailings or residue. In some mills these last-named men may be dispensed with; in others, two would not be sufficient for the work, the demand varying in different mills according to local conditions, the conveniences for handling the material, and the disposition made of it after having passed over the amalgamating tables.

As an average, six men may be considered necessary for a mill of the above-named capacity.

The cost of labor of the class chiefly required in mills is, on the average, $3 50 per day. Higher wages are paid to foremen and engineers, according to ability. Estimating the price of all labor at $3 50 per day, it appears from the statements of the various mills, as shown beyond in tabular form, that the cost for labor, per ton of rock, varies from 75 cents to $2, the average being very nearly $1 25, or possibly a little more.

The cost of iron consumed in the wear of shoes and dies is stated by some mill men at $2 per cord of rock, or from 25 to 30 cents per ton. Taking the cost of repairs, as stated in the following table, and applying it to the capacity of the several mills, the average cost per ton of rock appears to be 35 cents.

The cost for water, not for power but for use in crushing, is a considerable item of expense to those mills that are under the necessity of purchasing it. Water is delivered by the Consolidated Ditch Company at the price of $1, or sometimes $1 50, per inch. This is the inch of miner's measurement, or the quantity of water that will flow through an orifice one inch square in the side of the measuring box, under a certain pressure which, in this region, is understood to be six inches. Three inches of water, by this measurement, are required by the Ophir mill,[1] for which $3 are paid per diem, or about 18 cents per ton of rock.

The loss of quicksilver, in the milling process, which is chiefly mechanical, a portion being swept away and carried off in the tailings, varies between one-twentieth and one-tenth of a pound per ton of rock. Its cost is about $1 per pound, in currency, amounting, therefore, to 5 cents or 10 cents per ton.

Adding together the various items referred to in the foregoing paragraphs, we have the following: For fuel, $1; labor, $1 25; castings and ordinary repairs, 35 cents; quicksilver, and water (when purchased), 25

[1] According to these data, the consumption of water in milling at the Ophir mill is about 400 cubic feet per ton. Many of the mills situated in Nevada Gulch are dependent on the Ditch Company for their supply, and as this is cut off in winter, they are unfortunately obliged to lie idle several months.

cents, making a total, including water, of $2 85; or, without water, of $2 60 per ton. Making due allowance for other supplies, not enumerated, extraordinary repairs and miscellaneous expenses, the estimated cost will accord closely with the figures just given as the result of the experience of the Ophir and the Sensenderfer mills. Of course the above items will vary considerably in different mills; the cost of fuel depends not only on the price paid for it but on the economy with which it it used, the kind of boiler employed, and the proper adaptation of all the machinery to its purpose; the same remark applies to the economy of labor, while in all mills an essential condition of cheap work is constant employment at full capacity. In the presence of favorable conditions, in every respect, the cost of milling may be something, perhaps considerably, less than that just stated, while in their absence it will increase accordingly.

In water-power mills, as may be seen in the table given on a following page, the cost of working is very much reduced below that of steam mills. The cost of fuel is not only spared but the labor of the engineers and the expense of keeping the engine in order is also saved.

The mill of Miley and Abbe, on North Clear Creek, has an excellent water-power and is very well arranged for economical work. According to the statements of the owners, as set forth in the following table, the cost of treating rock in this mill is 80 cents per ton.

In the mill of Miley and Johnson, at Missouri City, the cost is said to be much less even than the foregoing, amounting to only 66 cents per ton. Such economy as is shown by these figures goes far toward balancing the disadvantages, already referred to, to which a water-power mill is subject, such as the occasional lack of water, the distance from the mine, and consequent liability to interruption in the supply of rock.

YIELD OF THE ORE.—The yield of the rock obtained by the ordinary crushing and amalgamating process, has been already stated as varying between 4 and 15 ounces of crude bullion per cord of ore. The average yield, throughout the district, is probably 6 or 7 ounces per cord. Precisely what this is per ton is only to be arrived at, under the present methods of doing business, by a careful guess.

The quantity of rock sent to the stamps is not very closely noted. Few

mines or mills incur the expense of weighing anything but first-class ore; the stamp rock is roughly measured as so many wagon loads, or car loads, and the quantity expressed in wood-choppers' terms as so many "cords." The weight of a cord of ore is variable, depending on its character. A cord of quartz, or poor vein-rock, unmixed with heavier minerals and broken in fragments of the size suitable for stamps, when loosely packed in a wagon or measuring box, would hardly weigh more than six tons and a half, or, if more closely packed, seven tons. A cord of pure iron pyrites, broken and packed in same manner, would weigh nearly twice as much. The weight of a cord of ore, therefore, depends on the proportion of pyrites mixed with the rock and the degree of fineness to which the stuff is broken, or the amount of space in the measuring box unoccupied by solid matter. According to these conditions a cord may weigh seven, eight, or nine tons or more. The average of seven and one-half is probably not far from the truth.

The difficulty of getting at the yield, precisely, is still further enhanced by the fact that it is commonly stated in "ounces." This means ounces of crude bullion, or retorted amalgam, which varies in value according to the amount of silver, base metals, and other impurities contained in it, and, as has been already shown, may be between $12 or $13 and $18 in coin. This value, moreover, may be expressed by some mill-men in coin, by others in currency, the relation of which to coin is also variable, so that to obtain the desired information, with something like a satisfactory degree of precision, demands a persistent inquiry that sometimes appears to a busy mill-manager to be an unwarrantable curiosity about other people's affairs.

Considering the cord of ore equal to seven and one-half tons, and the average yield of the cord six ounces of retorted amalgam, worth $16 50 per ounce, the average yield of the ton of rock may be stated at $13 20 in coin. This accords very closely with the average deduced from the statements of many of the mill-men, which, as shown in the table of milling operations, amounts to $13 30, coin, per ton.

Estimating the average yield of the cord of ore at seven ounces and one-half of amalgam, as some do, the yield per ton would be one ounce, or $16 50 in coin. This, of course, refers to stamp-rock, leaving the first-class ore out of the question.

The percentage of the value contained in the rock which this yield represents cannot be very definitely stated, because the actual value of the ore before treatment can only be approximately estimated. But few assays of stamp-rock are made, and even if their number were multiplied many fold, the difficulty of getting fair representative samples of ore, in which the percentage of gold is not only very small but also very irregularly distributed, would stand in the way of obtaining absolutely certain results. The tailings afford more reliable samples, because by the crushing of the ore, and the consequent intimate mixture of its particles, the whole mass becomes more uniform in character; but in the course of the milling process there is, doubtless, a little, and possibly much, of the gold washed away in the stream and carried beyond recovery in the tailings. How much this may be is variously estimated and probably over-estimated by many. Judging, however, of the efficiency of the work by the contents of the tailings or residue alone, it would appear that the proportion of the original value of the ore that is extracted by the usual milling process, *not including* the subsequent product of the tailings, does not much, if at all, exceed 50 or 55 per cent. of the gold contained, and a small percentage of the silver, the value of which is, practically, unimportant.

In this connection the following results of some experiments made by the First National Mining Company are interesting. This company, while working their claim, on the Burroughs lode, adjoining that of the Ophir, caused a series of assays to be made of the ore before sending it to the crushing mill. The quantity treated during the last four months of 1869 amounted to over 1,100 tons. A sample, consisting of a shovelful of rock, was taken from the front and rear end of each wagon load of ore, as it was sent from the mine. The accumulated samples of each week were mixed together and crushed, and one sample for assay obtained from the lot; thus affording one assay for about 80 tons of ore. The table shows the number of tons crushed; the assay value, in coin, per ton, as determined by the method just described, showing the proportionate value of the gold and silver, the yield per ton in coin, and the percentage of value obtained. The last column shows the relation of the yield obtained to the assay value of the gold alone, disregarding the silver, since the percentage of that metal which is saved is not only very

small, in fact, but is left out of the account altogether by the banker who purchases the bullion.

| Date. | No. tons of ore. | Assay value in coin per ton. | | | Yield per ton in coin. | Percentage of total value obtained. | Percentage of gold value obtained. |
|---|---|---|---|---|---|---|---|
| | | Gold. | Silver. | Total. | | | |
| 1869. | | | | | | | |
| September | Four lots amounting to 316 tons. | $23 35 | $3 36 | $26 71 | $10 00 | 37.0 | 42.8 |
| | | 20 04 | 1 56 | 21 60 | 12 00 | 55.0 | 60.0 |
| | | 24 80 | 15 08 | 39 88 | 6 50 | 16.3 | 27.0 |
| | | 22 73 | 15 47 | 38 20 | 9 85 | 26.0 | 43.0 |
| Week ending October 16 | 87 | 25 83 | 3 90 | 29 73 | 12 32 | 41.4 | 47.0 |
| Week ending October 23 | 60½ | 20 67 | 2 86 | 23 53 | 7 72 | 32.8 | 37.0 |
| Week ending October 30 | 77 | 23 77 | 2 99 | 26 76 | 9 00 | 33.6 | 38.0 |
| October 9 to January 1, 1870 | *a* 850 | 25 13 | 1 94 | 27 07 | 10 50 | 39.0 | 41.0 |

*a* Includes the three lots foregoing.

From this it appears that the proportion of gold obtained varies from 27 to 60 per cent. of the quantity originally contained in the ore, leaving from 40 to 73 per cent. remaining in the tailings. This is, of course, based on the assumption that the original assays of the ore fairly represent its true value. This may or not be the case, as the difficulty of obtaining fair average samples of such ore has been already pointed out, and the apparent want of uniformity in the results of working the several lots of ore, quoted in the table, is itself one indication of this difficulty; but making all due allowance for this, the general result of the experiments may be regarded as an approximation to a truthful expression of the relation existing between the value and the yield of the ore in the case referred to. It would, however, be unfair to accept this result as the expression of that relation in the case of all the ores in the district, inasmuch as this experiment is based on the working of ore from only one mine in a single mill; and, further, the average yield of the ore in question is 25 per cent. less than that already shown to be the average yield of milling ores throughout this region.

As a check upon the original assay of the ore the manager of the same mine has recently caused some assays to be made of the tailings, or residue of the ore after it has been milled. The following are the results of two different lots:

| Original assay value of ore in coin per ton. | Yield obtained in coin per ton. | Per cent. | Assay value of tailings in coin per ton. | Per cent. |
|---|---|---|---|---|
| $17 31 | $6 68 | 38.58 | $10 71 | 61.87 |
| 20 97 | 6 86 | 32.70 | 10 92 | 52.07 |

The average value of the tailings, produced by the mills of the district, is variously estimated; but they are generally believed, by those who have given much attention to the subject, to contain about $10 or $12 per ton, in gold, and $2 or $3 per ton, in silver.

The following statements present the results of a number of assays of raw tailings, or such as have not been subjected to any method of concentration.

The first of the two series of assays, given below, was furnished to the writer by Professor N. P. Hill, manager of the Boston and Colorado Smelting Works. These assays represent a better quality of tailings than the general average throughout the district. Some of them were old, produced years ago, when the richest ores, which are now smelted, were crushed and amalgamated in stamp-mills. They are given here to show the value of the better class of tailings; while the second series of assays, made by Mr. A. von Schulz, is believed to represent more correctly the average quality of tailings produced at the present time:

*Statement of Assays of Raw Tailings from the records of the Boston and Colorado Smelting Works.*

| | Ounces of fine gold per ton of 2,000 lbs. | Value of gold per ton. | Ounces of fine silver per ton of 2,000 lbs. | Value of silver per ton. | Total assay value of tailings per ton. |
|---|---|---|---|---|---|
| Samples of old tailings of Bobtail ore - - - - - - | 1.29 | $26 66 | 5.18 | $6 68 | $33 34 |
| Do. do. - - - - - - | .97 | 20 04 | 5.34 | 6 90 | 26 94 |
| Samples of old tailings of Bobtail ore, (Sensenderfer) | 1.21 | 25 01 | 4.13 | 5 32 | 30 33 |
| Samples of more recent tailings—Burroughs lode - | 1.07 | 22 11 | 3.31 | 4 27 | 26 38 |
| Do. do. do. | 1.28 | 26 45 | 1.92 | 2 47 | 28 92 |
| Do. do. do. | .96 | 19 84 | 3.87 | 5 40 | 25 24 |
| Samples of more recent tailings—Gregory lode - - | .96 | 19 84 | 4.96 | 6 38 | 26 22 |
| Samples of more recent tailings from Kimber's Mill | .64 | 13 23 | 5.83 | 7 51 | 20 74 |
| Average value of eight samples - - - - - - | - - | $21 65 | - - | $5 61 | $27 26 |

*Statement of Assays of Raw Tailings, made by Mr. A. von Schulz.*

| | Ounces of fine gold per ton of 2,000 lbs. | Value of gold per ton. | Ounces of fine silver per ton of 2,000 lbs. | Value of silver per ton. | Total assay value of tailings per ton. |
|---|---|---|---|---|---|
| Sample No. 1 | 0.24 | $4 96 | 3.64 | $4 73 | $9 69 |
| 2 | 1.70 | 35 13 | 3.64 | 4 73 | 39 86 |
| 3 | 0.73 | 15 08 | 2.91 | 3 78 | 18 86 |
| 4 | 0.37 | 7 64 | 0.85 | 1 10 | 8 74 |
| 5 | Traces. | - - | 1.70 | 2 21 | 2 21 |
| 6 | Traces. | - - | 7 29 | 9 47 | 9 47 |
| 7 | Traces. | - - | 1.21 | 1 57 | 1 57 |
| 8 | Traces. | - - | 1.15 | 1 50 | 1 50 |
| 9 | Traces. | - - | 1.45 | 1 88 | 1 88 |
| 10 | 0.25 | 5 17 | 2.10 | 2 73 | 7 90 |
| Average value of ten samples | - - | $6 80 | - - | $3 37 | $10 17 |

Assuming that the tailings contain, on the average, $11 per ton, in gold, disregarding the silver, and that the value of the gold obtained by milling is $13 50 per ton, it appears that 55 per cent. of the gold in the ore is extracted by the crushing and amalgamating process. To this, in order to ascertain the total percentage of value obtained from the ore, should be added the product subsequently derived from working the tailings; and if, as may appear from what follows, this latter item amounts to 15 per cent. of the original value of the gold, the total percentage extracted in the stamp mill may be placed at about 70 per cent.

Treatment of the Residues, or Tailings.—It has been already shown that after the ore, crushed by the stamps, has run over the amalgamated copper-plates of the tables, it is variously treated in different mills. In some it is allowed to pass away in the tail-race without further attention; in others it is collected outside in dams and worked over by some simple methods of concentration. In many mills the tailing stream passes first over blanket sluices; the product of the blanket washings is then either ground and amalgamated in Bartola pans or sold at the Smelting Works; while the great mass of the tailings, having passed over the blankets, is subjected to still further processes of concentration. In one or two mills Rittinger tables are used. The dressed tailings, or the products of all these various methods of concentration, are, in most cases, finally sold at the Smelting Works, where

the processes employed for their further treatment, as will be shown further on, are such that not only a large percentage of the remaining gold, but also of the silver and copper are extracted. Some of the methods of concentration will be briefly noticed before proceeding to describe the Smelting Works.

The blanket sluices resemble generally those that have been already described in the chapter treating of milling in Nevada. They consist of a simple sluice or flat-bottomed trough, one or two feet wide and of indefinite length, the sides of which are formed by two strips of wood, two or three inches high. The sluices are slightly inclined, so that the stream may flow readily. On the bottom of the sluices are laid coarse blankets. The stream of tailings is allowed to run over these sluices and the heavier particles of ore lodge in the blanket, while the lighter particles are swept away. The blankets are washed out at regular intervals. The material obtained is usually a rich concentration. One lot of over 14 tons of blanket tailings sold by the Ophir mine to the Smelting Works gave, by assay, 12 ounces of fine gold and 10 ounces of fine silver to the ton. The price paid for this lot was $210 per ton. Their yield, however, is not regular, and not often so high. In the Ophir mill they are usually treated in a small Bartola pan, a machine resembling somewhat in general character the common grinding pan described in a previous chapter; the yield obtained varies very much, sometimes quite high, sometimes quite low, but is most frequently stated at about $20 or $25 per ton, in coin. The greater part of the tailings is subsequently treated in common square buddles. The buddle is a long wooden box, about 4 or 5 feet wide, 10 feet long and 15 inches deep, fixed at a gentle inclination, so that the stream may run down through it readily, and so arranged that water may be supplied at the head, or upper end, and distributed evenly over the whole width of the table. The tailings are fed at the top, being thrown upon an apron above the head and washed down into the box by the stream. The workman, standing at the side, by means of a broom or light scraper assists the even distribution of the material, and by sweeping it very gently upward, toward the head of the box, aids the separation of the heavier from the lighter particles, the former remaining near the head, the lighter being swept away by the current. When the buddle is full the contents are divided into three equal parts; that

which is nearest the lower end being allowed to run away, the middle portion returned to the apron to be treated again in the buddle as just described, while the headings, or the three feet nearest the upper part of the buddle, being the richest, is treated in a "keeve;" that is, agitated or stirred in a barrel or tub, and then allowed to settle, the heavier part collecting on the bottom, being the concentrated mineral; the upper portion of the stuff in the tub is returned to the buddle for a repetition of the process. Two men or a man and a boy are required to work one buddle. Tailings are generally dressed in this way at a cost of from $4 or $5 to $8 per ton of dressed tailings, according to various circumstances, mainly, the degree of concentration attempted. It is usually estimated that six tons of common or raw tailings produce one ton of dressed tailings.

At the Ophir mine the price paid for buddling was $7 per ton of concentrated material produced, of which the average assay gave two and one-third ounces of fine gold and five ounces of fine silver per ton. The dressed tailings were sold at the Smelting Works at about $17 or $18 per ton. At the Brastow mill some old and rich tailings of high grade ores were concentrated in this manner so as to contain about four ounces of fine gold to the ton, and were sold at the Smelting Works at prices varying from $40 to $52 per ton.

The following statement, furnished by Professor Hill, shows the gold and silver contained in various lots of dressed tailings purchased at the Smelting Works:

| Tailings produced from— | Tons. | Containing ounces of fine gold per ton— | Containing ounces of fine silver per ton— |
|---|---|---|---|
| Ores of Bobtail lode, Bobtail Company | 13 | 2.5 | 2 |
| Ores of Bobtail lode, Trust Company | 97 | 3.81 | 6.3 |
| Ores of Bobtail lode, Sterling Company | 24 | 2.83 | 2.66 |
| Ores of Gregory lode, Gregory Consolidated Company | 5.5 | 2 | 2 |
| Ores of Burroughs lode, Ophir Company | 179 | 2.36 | 5 |
| Ores of Burroughs lode, Gilpin Company | 25 | 2 | 4 |
| Ores of North Star lode, Illinois Company | 77 | 1.6 | 5 |
| Ores of sundry lodes | 400 | 1.5 | 4 |

The price paid by the Smelting Company for these buddled (not blanketed) tailings varies from \$13 to \$45 in currency, the average, perhaps, being about \$20 per ton.

In order to form an approximate estimate of the total percentage of the gold that is extracted by the stamp mill, we may assume, from the data already stated in the foregoing pages, that 55 per cent. of the whole is obtained by the first crushing and amalgamation in the batteries and on the tables, leaving 45 per cent. in the tailings. Assuming, further, that the average value of the gold in these tailings is \$11 per ton, and that six tons, containing \$66, are concentrated into one ton, the yield of which, taking a general average of the product derived from working those that are blanketed, and from the sale of those that are buddled, may be placed at \$22, it follows that one-third of the value of the raw tailings, or 15 per cent. of the original gold value of the ore, is extracted by processes subsequent to the first crushing and amalgamation; which, being added to the 55 per cent. previously obtained, gives a total of 70 per cent. for the whole course of treatment.

It should be observed that when tailings are sold to the Smelting Works and there treated by the method to be described presently, instead of being worked in pans, as they frequently are in mills, the actual value extracted from them is considerably greater than that on which the above calculation is based.

The mills and milling methods of the gold-producing regions of Colorado are doubtless capable of many improvements, but it seems clear that in the present state of metallurgical science, the local condition of the country, the costs of labor, materials, &c., the stamp mill affords better means of working the low-grade ores than are offered by any other method yet attempted. Compared with all others it possesses the advantage of cheapness—a requisite condition in treating ores of such low average value, and, even in this particular, important improvements may be, and gradually are, being made.

One great desideratum, in order to improve the efficiency of the process, and, at the same time, to reduce the cost of working, in some respects, appears to be the adoption of some suitable method of concentration, which, being combined with the present process of crushing and amalgamation, should ren-

der available the contents of the tailings in a more perfect and less expensive manner than is now done by the means generally employed.

It has been already shown that, by the ordinary operation of crushing and amalgamating, about 50 or 60 per cent. of the gold contained in the ore is extracted, while nearly all the silver, and, practically, all the copper, are allowed to be wasted. The value of these two metals, in a ton of ordinary ore, is too low to admit of their profitable extraction, except by some preliminary process of concentration, by means of which the valuable contents of several tons are brought into one ton, that may then be treated by smelting, or other suitable methods.

Any method of concentration, however, first requires the crushing of the ore, and that, in the present condition of milling experience, can hardly be done better than by the best and most improved stamp mills. If, therefore, the present system of crushing and amalgamating be retained, by which means a considerable percentage of the free gold is obtained, and the crushed product be then delivered, without rehandling or passing out of the mill, to the best kind of concentrating machinery, the concentrated product would contain not only nearly all the remaining gold, but also the greater part of the silver and copper, the whole of which could then be submitted to smelting, or other suitable processes, by which a very large percentage of its value should be profitably extracted.

The desired improvements in concentration appears still more important when it is remembered that ores vary much in character, and that, in some, only a small percentage of the gold contained is readily available for amalgamation, as practiced in the battery and on the tables. Whether this be due to the form in which the gold exists in the ore, or to some peculiar condition of the quicksilver, or to some other cause not fully understood, may be an open question; but it has often been observed by mill-men that ores having an equal value, when subjected to apparently the same process, will sometimes afford very different yields, some giving a high and others a low percentage of the value contained. A low yield, involving, under present conditions, a large loss, would be less important if, beyond the crushing and amalgamating machinery, there were other ample and efficient methods of concentration provided, by which the mineral that had escaped from the batteries and

tables without satisfactory treatment, would be certainly collected for a subsequent and more effective process.

Further, by providing proper means of concentration which should save all, or nearly all, the valuable portion of the crushed product, the capacity or duty of the stamps could be greatly increased, and the expense, per ton, be thus considerably diminished. It has been pointed out that the speed of the stamps is very low, some making only 15 drops per minute, and the average, in the district, probably not exceeding 28 drops per minute. With this speed the amount crushed is, on the average, less than one ton, per stamp, per day, and probably less than one-half the average quantity crushed, per stamp, in any other extensive mining region in the country, where a similar method of wet-crushing is employed. It is obvious that, if the quantity of rock crushed, in a given time could be doubled without much increasing the cost of labor, fuel, or other materials, the expense, per ton, would be very largely reduced. It is urged by many that the necessity for slow crushing is due to the peculiar condition of the gold, which, it is said, requires a long time for amalgamation in the battery. However this may be—and some experience already noted on page 555 makes it doubtful—it is still probable that the increased percentage of gold saved by protracted crushing is a comparatively insignificant proportion of the whole amount obtained, and might be more economically saved by appliances provided outside the battery. In this particular, improved methods of concentration would to be useful.

Some experiments were made last summer, at the Black Hawk mill, with the view of adopting improved concentrating machinery. A Rittinger percussion table was constructed and set up outside the building, and a lot of tailings were treated upon it. The table was not advantageously placed, nor established under so favorable conditions as would be provided for permanent use, but the results obtained, with the experimental lots that were worked were very satisfactory, and it was then decided to build a sufficient number and place them in the mill in front of the batteries and short amalgamating tables, so that the crushed ore, after having yielded what it might to the quicksilver, could pass at once on to the tables and there be concentrated. The writer has been unable to learn under what conditions these tables were set up, or with what degree of success they have been operated; but the very

satisfactory results that have been generally obtained by the Rittinger table in Europe leads to the opinion that it should be well adapted to the treatment of our ores, in Colorado and elsewhere. It has already been described in one or two works published in this country, but it is deemed of sufficient importance to be noticed here, in connection with the subject under consideration.

The following description of this percussion table is taken from Von Rittinger's Lehrbuch der Aufbereitungskunde.[1] The drawings on Plate XXXIV, copied from the Atlas accompanying the above-named work, show the details of its construction. Fig. 1 is a front elevation of a double table; Fig. 2 a plan; Fig. 3 a side view; Figs. 4, 5, and 6 show other details, to be noticed further on. This apparatus consists of a wooden table, or platform, about four feet wide and eight feet long, which is suspended by iron rods at the four corners, as shown at *b*, *b*, Figs. 1, 2, and 3, presenting an inclined plane, over which the water and material, supplied at the upper end, may flow evenly toward the lower end. The table is so hung as to move freely, in a lateral direction, when acted upon by a cam, *c*, and may be thrown back by the action of a spring, *d*, so as to strike forcibly against a timber, *e*, firmly imbedded in the ground, by which means a shock is imparted to the table and the material upon it.

The characteristic features of this table, as compared with the ordinary percussion table, already many years in use, are that the shock is applied at one of the long sides instead of at the end, and that it is self-discharging and continuous in its operations. On the old-fashioned percussion table the material being supplied at the upper end and evenly distributed across the width of the table by a stream of water, and the shock being likewise imparted at the same end, the tendency of the heavier particles is to move backward at each throw, or shock, of the table, while the lighter particles, following the impulse of the stream, move downward toward the front edge and are there discharged. In the case of the Rittinger table all the particles which are fed

[1] Since the above description was written and the accompanying Plate engraved, the first supplement to Von Rittinger's treatise (Erster Nachtrag zum Lehrbuche der Aufbereitungskunde) has been received. It describes several modifications in the construction and application of the continuous percussion table, for which, in detail, the reader must be referred to the original source, but the most important of which are noted here.

at the upper end and near one side, move downward with the stream, but as the percussion is applied at the opposite side, they obtain, at each throw of the table, a lateral motion, which varies in amount according to the density of the particles, so that the heaviest, the grains of ore, move entirely across the table to the side opposite to that at which they entered; the lighter particles, or grains of ore and gangue combined, move part way across, while the lightest, or grains of earthy character, move downward in a nearly straight line, describing curves such as are shown in Fig. 2, at $a$, $a^1$, $a^2$, $a^3$, $a^4$. By this means a separation of the particles is effected according to their density, and as they are discharged at different parts of the front edge of the table, they may be received there in separate vessels or troughs, provided for the several classes, the first, consisting of nearly pure ore, being ready for smelting, or other metallurgical treatment; the second, consisting of mingled ore and gangue, may be returned for repeated dressing; and the third, nearly pure gangue, is allowed to run to waste.

Fig. 4 shows the construction of the frame of a double table, consisting of two cross-pieces, *f*, and five longitudinal pieces, *g*. This frame is covered by hard-wood plank or boards which are smoothly dressed and carefully fitted together, forming the surface of the table over which the material for concentration is allowed to pass.[1] The sides and upper end of this surface are furnished with bordering strips of wood, *h*, and a similar strip divides the surface longitudinally in the middle, thus forming a double table. The lower end of the table is also furnished with short strips, *i*, which may be moved on a pivot[2]

[1] As the top of the table, hitherto constructed of maple boards, soon begins to rot or wear upon the surface, and thus to lose its desired smoothness, it is better to cover it with a stout, water-proof gum cloth, which must possess the requisite degree of smoothness or polish, so that the fine particles of slime may not adhere to it, and should be white or of light color, so that the dark streaks of ore may be clearly distinguished. The cloth should be applied to the table when warm, so that it may be well stretched under ordinary temperature. When stretched and nailed upon the table, the edges of the cloth are covered with narrow strips of leather, in order to prevent tearing; and at the upper end it is covered with a strip of zinc, 10 or 12 inches wide, upon which the water and solid material fall from the distributing boards, passing thence quietly on to the cloth. Such a cloth-covering is said to last over a year, and to be especially well adapted to the treatment of the finest material; only the number of shocks must be increased for such to 120 or 150 per minute.

[2] These pointed strips may also be fixed in any desired position or place by driving wooden wedges between them and a transverse piece of wood that crosses the table

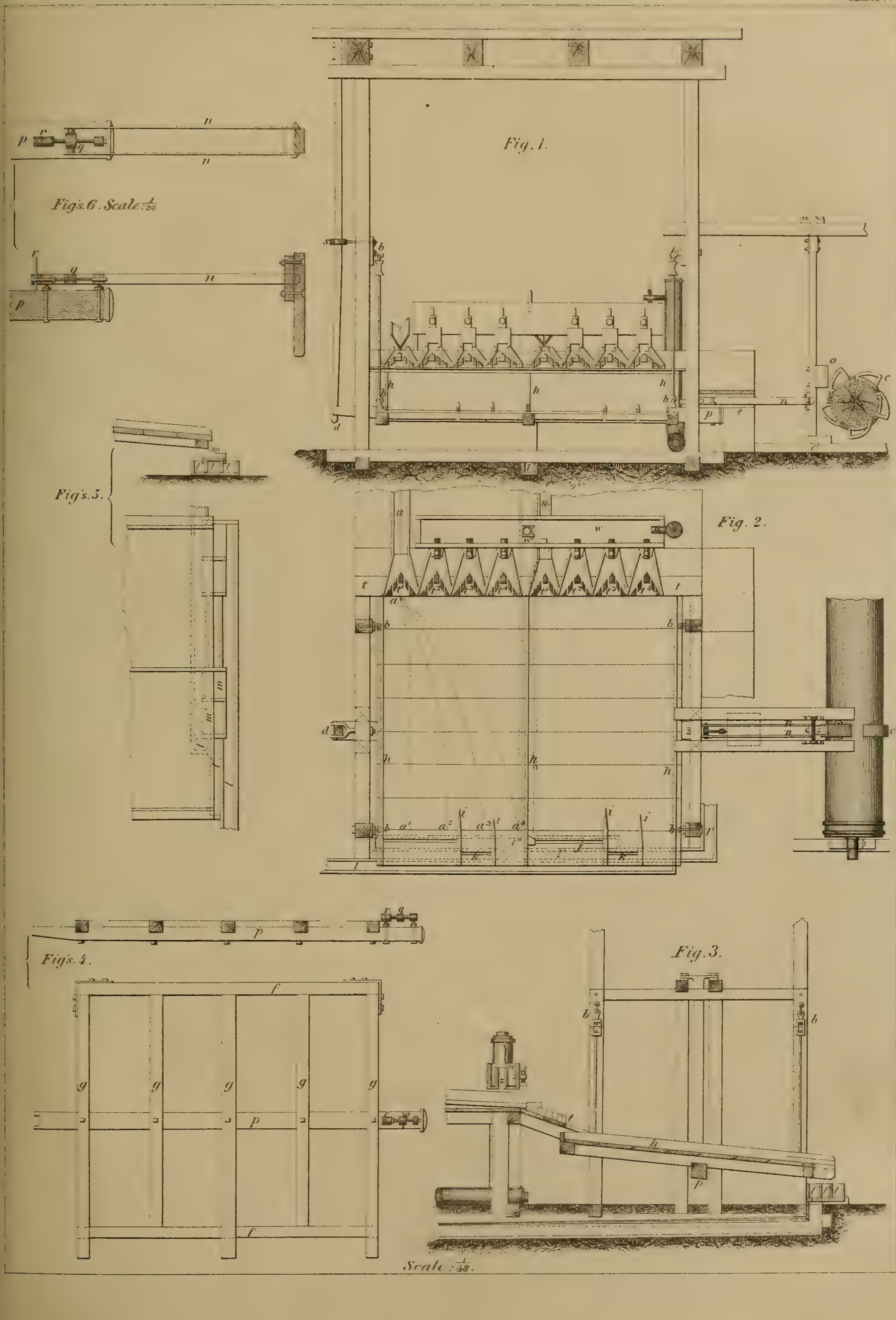
Fig. 1.
Fig. 2.
Fig. 3.
Fig's. 4.
Fig's. 5.
Fig's. 6. Scale: 1/24
Scale: 1/48.

toward one side or the other, and the upper ends of which are pointed, so as to assist somewhat in the division of the several classes of the material at the place of discharge.

The lower end of the table is also pierced with slits, or apertures, *j* and *k*, Fig. 2, through which the material may be discharged from the table before reaching the lower edge, falling thus into troughs, or launders, which conduct the different assortments to their appropriate places. The outer one of these launders, *l*, receives the clean ore from the lower edge of the table; the second, *l'*, receives the "middlings" through the aperture *k*; and the inner, *l''*, receives the waste stuff through the aperture *j*.

Another arrangement for the disposition of the assorted material, without the use of apertures, is shown in Fig. 5, in which the poor stuff, or gangue, is discharged over the edge of the table into the launder *l''*; the other two classes fall into the box *m*, which is divided into two parts, opening in opposite directions, that part which is under the discharging point of the clean ore opening to the right and delivering the stuff into the launder *l*, the other part receiving the middlings and delivering into the launder *l'*. The table is suspended in an upright framework, as shown in the drawing, by iron rods, the length of which may be somewhat increased or diminished, as may be desired, by means of the screw near the point of support. The percussion timber, *p*, forms a part of the frame of the table. One end of it rests against the timber *e e'*; being strongly pressed in that direction by the spring, *d*, which is attached to the other end. Motion is communicated to the percussion timber *p*, and thus to the table by rods, *n*, which connect it with a perpendicular rod, *o*, against which the cams, *c*, strike. The rods *n* are attached to *p* by means of a nut, *q*, shown in Fig. 6, which moves on a screw, and may be adjusted, for the purpose of shortening or lengthening the stroke by turning the head, *r*. When the cam, *c*, presses against the block at *o*, it moves the table in a lateral direction, compressing the spring, *d*, which latter, as soon as the pressure of the cam is relieved, throws the table back against the timber, *e*, producing the shock, the force of which is regulated by a screw, *s*, applied to the middle of the spring and entering the framework above the table. The force of the stroke

---

near the lower end and is supported above it by resting on the upper edges of the side and partition strips, *h*, to which it is nailed.

is increased by screwing the spring up closer to the frame, or diminished by withdrawing the screw.[1]

The distributing board, *t*, is divided into four parts, or aprons, for each single table, each of which aprons is provided with a group of distributing points. The material for concentration is supplied from a trough, *u*, and enters the table by the apron $t'$. Clear water, of which a supply is kept in the box *w*, the surplus flowing off through $w'$, is furnished thence, through separate cocks, to the aprons $t^2$, $t^3$, and $t^4$, and thus distributed evenly over the table. In the manipulation of this table the following conditions are important: The surface of the table must be made as smooth as possible. The width of the apron from which the material for concentration is supplied to the table should not exceed 8 or 12 inches, clear water being distributed over the remainder.

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[1] In the improved arrangement, motion is imparted to the table in a somewhat different manner, the cam acting directly upon the frame instead of by the means shown in Fig. 1; and drawing the table to one side and then releasing it for the movement in the opposite direction, by which it receives the shock, instead of pushing it as indicated on Plate XXXIV. To effect this (the contrivance cannot be very clearly described without the aid of further drawings) the end of the percussion timber, *p*, nearest the cam is furnished with two stout iron plates, one attached to each side of the timber and extending toward the cam; the two plates are connected at their other ends by a cast-iron piece which fills the space between them, and the inner surface of which is curved so as to correspond to the curve of the cam. The latter revolves between the two plates, in the reverse direction from that indicated in Fig. 1, and, striking against the cast-iron piece, draws the table to one side. When the table is released by the cam it is drawn to the opposite side by the action of a spring, which, as in the case already described, is of wood, but is placed horizontally, the two ends being fixed and the middle attached to the end of the percussion timber. When thus drawn forward the end of the percussion timber strikes against a buffer, which is firmly secured in an iron bed-plate that is screwed down to an underlying timber; and as the sharpness of the shock—an important condition for effective work—depends upon the firm position of this timber, the latter is made long enough to extend entirely under the table to the opposite side, and is fixed by holding-down bolts to a solid foundation of masonry. The timber is connected with and braced by other timbers that are so laid in the masonry as to distribute the shock as evenly as possible to the entire mass of the latter. The opposite end of the timber may serve as the foundation for the supports of the cam-shaft, one end of which is furnished with a driving-pulley and the other end with a 400-pound to 600-pound fly-wheel, 3 feet in diameter.

The movement of the table is guided by two uprights, one on each side of the percussion timber.

The buffer is adjustable, and by advancing or retiring it, the length of the stroke may be regulated.

If a very clean product is desired the width of the washing surface may be increased to 4 feet, making a total width of 5 feet; or, maintaining a total width of 4 feet, the distributing surface of the slimes may be reduced to a width of 8 or 9 inches. The inclination of the table must be adapted to the character of the material to be treated; it should be about six degrees for sands and three degrees for fine slimes. The supply of stuff to be treated should not exceed $\frac{2}{10}$ of one cubic foot, containing 15 pounds of sands per foot; or $\frac{1}{10}$ of one cubic foot, containing 6 pounds of slimes per foot. According to this a double table will treat in 24 hours 4.640 tons of sands, or 0,864 tons of slimes. The amount of clear water required is about the same quantity per foot of distributing breadth as that which brings the ore upon the table; so that if the breadth of the ore-distributing surface is one foot, and that of the water-distributing surface is three feet, the quantity required for one table will be for sands $\frac{6}{10}$ of one cubic foot per minute; and for slimes, $\frac{36}{100}$ of one cubic foot per minute. The quantity of clear water must, further, be increased as the inclination of the table is decreased. The outer edge of the table, that is the side opposite that on which the ore enters, should have a little more water than the rest of the surface, in order to carry off the heavier material that reaches that side. The number of strokes per minute is, for sands, 70 to 80; for slimes, 90 to 100. The length of each stroke depends upon the tension of the spring, *d*, by which the table is pressed against the block, *e*. The spring has a length of 11 feet, a breadth of 3 inches, and a thickness of 2 to 2½ inches. If the spring has a tension of 180 or 200 pounds, the length of stroke should be for sands 2½ inches, and for slimes ½ to ¾ of an inch.

Under too strong tension of the spring the table makes its return movement too speedily for the desired action of the particles; the result is that they move in the reverse direction. The operation of the table demands great uniformity in treatment, especially as regards the number of blows and the quantity of water and of material. When the stream carrying the material upon the table contains less sand or slime per cubic foot than the maximum above given, the tension of the spring should be relieved and the inclination of the table diminished. Under ordinary conditions the average performance of a double table is from two to four tons in twenty-four hours, with a consumption of water of 1,000 or 1,500 cubic feet. One table requires ¼ horse-power.

*Statement concerning the Operations of*

| Name of mill. | Location. | When built. | Approximate cost—currency. | Stamps. | | | | Quantity crushed per day in tons. | Yield of rock in coin per ton. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | No. of stamps. | Weight in lbs. of each stamp. | Fall in inches. | No. drops per minute. | | |
| New York - - - - - | North Clear Creek | 1861–1869 | $35,000 | 55 | 550 | 12 to 14 | 28 to 30 | - - | $11 72 |
| Hurd's - - - - - - | North Clear Creek | 1868 | 20,000 | 26 | 660 | 14 | 25 to 35 | *a* 17 | 12 00 |
| Black Hawk - - - - - | Black Hawk - - - | 1865 | - - | 60 | 850 | 14 | 15 | 30 | 10 00 |
| Polar Star - - - - - | Chase Gulch - - - | 1867–1869 | *b* 30,000 | 24 | 425 | 14 | 30 | 15 | *c* $10 to *d* $21 |
| Chicago - - - - - - | North Clear Creek | 1863 | 15,000 | 20 | 450 | 14 | 40 | 15 | - - |
| Nesmith & Company - - | Black Hawk - - - | 1868 | 18,000 | 20 | 550 | 14 | 35 | 15 to 20 | 15 00 |
| University - - - - - | Black Hawk - - - | 1863–1868 | 10,000 | 15 | 500 | 15 | 30 | 11 to 12 | 9 00 |
| Holbrook - - - - - - | Black Hawk - - - | 1863 | 7,000 | 13 | 500 | 14 | 30 | 11 to 12 | 18 00 |
| Miley & Abbe's - - - | North Clear Creek | 1869 | 20,000 | 25 | 584 | 12 | 28 | 26 | 14 00 |
| Sensenderfer - - - - | North Clear Creek | 1863–1869 | 15,000 | 20 | 450 | 12 | 34 | 15 | *k* 24 00 |
| Holman - - - - - - | Black Hawk - - - | 1863 | - - | 12 | 400 | 12 | 22 | 7½ | - - |
| Bates - - - - - - - | Chase Gulch - - - | 1860 | - - | 8 | 425 | 12 | 30 | 7½ | - - |
| Smith & Parmelee - - - | Gregory Gulch - - | 1864–1869 | 25,000 | 25 | 550 | 14 | 35 | 22½ | 12 40 |
| Gregory, No. 1 - - - | Black Hawk - - | 1863 | - - | 20 | 850 | 14 | 15 to 17 | 13 | 10 00 |
| Star - - - - - - - - | Mountain City - - | 1860 | 6,000 | 12 | 500 | - | 40 | 7½ | 17 00 |
| Narragansett - - - - | Gregory lode - - | 1864 | 50,000 | 40 | 750 | 14 | 30 | 37½ | 13 50 |
| Montana - - - - - - | Central City - - - | 1865 | 90,000 | 30 | 750 | 12 | 40 | 30 to 37½ | - - |
| Pacific National - - - | Spring Gulch - - | 1864 | 28,000 | 24 | 600 | - | 35 | 22½ | 10 25 |
| Lexington - - - - - | Nevada Gulch - - | 1861 | 40,000 | 24 | - - | 18 | 36 | 15 | 9 00 |
| Gilpin Company's - - - | Nevada Gulch - - | 1862 | 25,000 | 18 | 500 | 16 | 28 to 35 | 11 to 12 | 10 75 |
| First National - - - - | Nevada Gulch - - | - - | - - | 25 | 900 | 14 | 28 | 22½ | 10 50 |
| Ophir - - - - - - - | Nevada Gulch - - | 1864 | 10,000 | 24 | 500 | 14 | 30 | 18¾ | 16 00 |
| Whitcomb's - - - - - | Nevada Gulch - - | 1860 | 8,000 | 12 | 430 | 13 | 32 | 11 to 12 | 10 50 |
| Quartz Hill Gold Mining Company. | Nevada - - - | 1865 | 20,000 | 12 | 550 | 16 | 22 | 7 | 11 00 |
| Blue - - - - - - - | Nevada - - - - | 1868 | 10,000 | 12 | 700 | 8 | 40 | 10 to 15 | 21 66 |
| Carondelet - - - - - | Quartz Hill - - - | 1869 | 3,500 | 12 | 350 | 12 | 50 | 21 | 6 60 |
| Gleason & Company - - | Nevada - - - - | 1869 | 2,000 | 8 | 650 | 15 | 27 | 7 | 15 40 |
| Miley & Johnson - - - | Missouri City - - | 1869 | 10,000 | 16 | 500 | 12 | 40 | 18 to 20 | 15 00 |
| Delaware - - - - - - | Russell Gulch - - | 1868 | 12,000 | 15 | 500 | 12 | 24 to 28 | 13 | 8 25 |
| Perrin - - - - - - - | Russell Gulch - - | 1869 | 20,000 | { 10<br>{ 12 | 450<br>600 | -<br>13 | 40 to 50 }<br>20 to 25 } | 15 to 18 | 7 25 |
| Lincoln - - - - - - | Russell Gulch - - | 1863 | 12,000 | 12 | 625 | 14 | 24 | 10 to 15 | - - |
| Beloit - - - - - - - | Lake Gulch - - - | 1860 | 6,000 | 12 | 450 | 16 | 24 to 32 | 5 to 8 | 25 00 |
| Trust - - - - - - - | Lake Gulch - - - | 1868 | 25,000 | 30 | 700 | 14 | 20 to 30 | 18 to 23 | 13 20 |
| Winnebago - - - - - | Central City - - - | 1868 | 20,000 | 20 | 500 | 15 | 30 | 15 | 8 50 |
| Eureka - - - - - - | Eureka Gulch - - | 1860 | 5,000 | 18 | 450 | 15 | 25 | 12 | 13 00 |

*a*. Quantity crushed is the work of 20 stamps.
*b*. $15,000 for water power.
*c*. Bates-Hunter ore.
*d*. California ore.
*e*. By water power.
*f*. By steam power.
*g*. Working Bobtail ore; very hard on shoes and dies.

35 *Stamp Mills in Gilpin County.*

| Power — steam or water. | Cords of wood used per day. | Cost of wood per cord, in currency. | Men employed. | | | | Cost per month for repairs, in currency. | Cost per month for water, in currency. | Loss of quicksilver in lbs. per month. | Cost of working per ton, in currency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Engineers. | Feeders. | Others. | Total. | | | | |
| Both | | | | | | | | | | |
| Steam | 2 to 2½ | $5 25 to $6 00 | 2 | 2 | 1 | 5 | $75 00 | - - | 20 | $3 00 |
| Steam | 5½ to 6 | 5 00 | 2 | 6 | 3 | 11 | 225 00 | - - | 60 | 2 25 to 2 75 |
| Both | 1½ | 5 50 | 2 | 4 | 1 | 7 | 75 to 90 00 | - - | 35 to 40 | *e* 2 00 to *f* 3 00 |
| Steam | 2¼ | 5 00 | 2 | 2 | - | 4 | 150 00 | - - | 12 | 2 40 |
| Both | 1½ | 5 00 | 2 | 2 | 2 | 6 | *g* 400 00 | - - | 20 | *h* 2 40 to *i* 3 33 |
| Steam | 2 | 5 00 | 2 | 2 | 1 | 5 | 200 00 | - - | 15 | 2 50 |
| Both | 1½ | 5 00 | 2 | 2 | - | 4 | 100 to 300 00 | - - | 16 | 2 50 to 3 00 |
| Water | None | - - | - | 3 | - | 3 | 80 00 | - - | 20 | *j* 80 |
| Water | None | - - | - | 2 | 2 | 4 | 75 00 | - - | 10 | |
| Steam | 1½ | 5 50 | 2 | - | 1 | 3 | 30 to 50 00 | - - | 20 to 30 | 3 00 |
| Steam | 1 to 1¼ | 6 00 | 2 | - | - | 2 | 30 00 | - - | - - | 2 50 |
| Steam | 3½ | 5 75 | 2 | 2 | 4 | 8 | 125 00 | - - | 25 | *l* 1 75 |
| Steam | - - | - - | - | - | - | 4 | 75 00 | - - | 16 | 2 25 to 2 75 |
| Steam | 1 | 6 00 | 2 | 2 | - | 4 | 100 00 | - - | - - | 3 50 |
| Steam | 3 | 8 00 | 2 | 4 | 1 | 7 | 150 00 | - - | 20 | |
| Steam | 3 | 7 00 | 2 | 2 | 3 | 7 | - - - | - - | - - | 2 00 |
| Steam | 2 | 7 00 | 2 | 2 | 5 | 9 | 25 00 | - - | - - | 2 66 |
| Steam | 2½ | 7 00 | 2 | 2 | 1 | 5 | 50 00 | $90 00 | - - | 3 50 |
| Steam | 2 | 7 50 | 2 | 2 | - | 4 | 60 00 | 50 00 | 30 | 3 33 |
| Steam | 4 | 7 00 | | | | | | | | |
| Steam | 3 | 7 00 | 2 | 2 | 1 | 5 | 369 55 | 84 00 | 20 | 3 33 |
| Steam | 1¼ | 6 75 | 2 | - | 1 | 3 | 100 00 | - - | 12 | 2 40 |
| Steam | 1½ | 7 00 | 2 | 1 | 1 | 4 | 30 00 | 20 00 | 5 | 3 33 |
| Steam | ¾ | 7 00 | 2 | - | 1 | 3 | 40 00 | - - | 2 | |
| Water | None | - - | 2 | - | 1 | 3 | - - - | 120 00 | | |
| Water | None | - - | - | 2 | 2 | 4 | 50 00 | 135 00 | - - | 1 60 |
| Water | None | - - | - | 2 | - | 2 | 60 00 | - - | - - | 66 |
| Steam | 1⅛ | 7 00 | 2 | 2 | 1 | 5 | 30 00 | 37 50 | 20 | 2 50 |
| Steam | 2 to 2½ | 5 00 | 2 | 2 | 3 | 7 | 250 00 | - - | - - | 2 66 |
| Steam | 1½ | 7 00 | 2 | 2 | - | 4 | 60 00 | 15 00 | | |
| Steam | 1¼ | 8 00 | 2 | - | 1 | 3 | 60 00 | - - | 25 | |
| Steam | 2 | 8 00 | 2 | 2 | 2 | 6 | 250 to 300 00 | - - | 15 | 2 66 |
| Steam | 1 | 7 00 | 2 | 2 | 2 | 6 | 50 00 | - - | 5 | 2 00 |
| Steam | 1¼ | 6 00 | 2 | 2 | - | 4 | 18 00 | - - | | |

*h*. Ordinary ore.

*i*. Bobtail ore.

*j*. When working on full capacity.

*k*. All from Sensenderfer mine, Bobtail lode.

*l*. An apparent oversight, since wood and labor (the latter at an average of $3 50 per day per man) would amount to more than $2 per ton.

Stamp Mills in Gilpin County.—There are about 70 crushing mills, large and small, in Gilpin County, or in the gold-producing region, chiefly situated in the neighborhood of Nevada, Central City, and Black Hawk. The number of their stamps exceeds 1,300. Nearly all of these were at work in the summer of 1869, although some of them are old and out of repair, and a few others were idle, for other reasons, at the time referred to. In order to obtain some desirable statistical information concerning the operations of these mills, the writer addressed a circular to their proprietors, or managers, making a number of inquiries on the subject. The foregoing statement presents in tabular form much of the information thus obtained, concerning those mills from which replies were received. The information is here given just as it was received from each mill manager, except that, in stating the capacity of the mill, "cords" of ore have been converted into tons at the average rate of $7\frac{1}{2}$ tons per cord; in stating the yield of the rock, "ounces" of crude bullion, per cord of ore, have been converted into dollars and cents per ton; and the cost of working is given per ton instead of per cord, the calculation being made on the basis above indicated. There are a few apparent inconsistencies in some of the statements which the writer prefers to leave uncorrected than to attempt unauthorized changes.

The following are mills not included in the foregoing statement:

| Name. | Stamps. | Name. | Stamps. |
|---|---|---|---|
| Remine's | 20 | Dickinson's | 20 |
| Walker's | 12 | Consolidated Gregory | 50 |
| Eagle | 20 | Fitzpatrick | 10 |
| Bobtail | 12 | Arrighi's | 3 |
| John Sensenderfer's | 20 | Empire | 12 |
| Union | 20 | Sterling | 23 |
| Briggs | 50 | Rocky Mountain | 20 |
| Bates and Baxter | 12 | Mather | 12 |
| Gunnell | 18 | Ruh's | 3 |
| La Crosse Company | 12 | Boston | 12 |
| Kansas-Colorado | 12 | Philadelphia | 25 |
| Stoner | 12 | New Bedford | 12 |
| Beverly | 12 | Gold Hill | 16 |
| Potter and Hawley | 15 | Vernon | 14 |
| Ayres | 12 | North Star | 22 |
| Morse | 12 | Waterman's | 15 |
| Kimber's | 12 | Gunnell Central | 24 |
| Pease and Mann | 10 | | |

Treatment of the first-class or smelting ores.—The works of the Boston and Colorado Gold Smelting Company are situated in Gregory Gulch below the town of Black Hawk, a half mile below the junction of Chase and Gregory Gulches. The business of this concern consists in purchasing the selected ores of higher grade from the various mines, as well as, also, the dressed tailings from the mills, and treating them by the process of smelting for the extraction of the gold, silver, and copper contained. By the methods thus far introduced at the works these metals are obtained in the form of "matt," which consists mainly of the sulphide of copper with sulphide of iron, containing, when concentrated to the required standard, from 50 to 60 per cent. of metallic copper, and having combined with it the gold and silver in varying proportions, but commonly about 40 or 50 ounces of fine gold and from 100 to 400 ounces of fine silver to the ton of matt. This crude metal, or matt, is at present shipped in that form to Swansea for refinement or parting of the several metals, as the necessary separation works have not yet been provided at the Colorado establishment. The works for the treatment of the matt, that is the ultimate separation of the metals, not only involve a large outlay of capital, but would, for economical operation, require a much larger supply of matt than could be furnished from the single smelting furnace at first provided. The company, therefore, deferred the construction of separation works until the business should be established upon a sufficiently broad and permanent basis. Within a year or little more the smelting capacity of the works has been doubled, additional furnaces having been built, and it is understood that the necessary works for the treatment of the matt will presently be added; when the whole process will be performed at the company's establishment at Black Hawk.

The metallurgical process, therefore, so far as it is carried at present in Colorado, is confined to the preliminary concentration of the metals; that is, the gold, silver, and copper that may be distributed through 10, 20, or 30 tons of ore, or tailings, are brought together by smelting into one ton of matt, or crude metal; the final separation and extraction of the several metals being done elsewhere by methods not yet introduced into the Territory.

The process employed for the production of the matt is not essentially different from that in use, during many years, in Europe, whence it was

brought. Its successful performance demands much practical skill and experience, but its general features are familiar to all metallurgists, and are described in various works that treat of such subjects.

An outline of the method of operations in the smelting establishment here referred to will suffice for the purpose of this chapter, while for a more minute description of the processes involved, the reader is referred to metallurgical treatises.

The ores, as they ordinarily occur, disregarding the accessory or associated minerals peculiar to some veins, which sometimes require modifications of the common course of treatment, consist essentially of iron and copper pyrites with a siliceous gangue, carrying from 3 or 4 to 10 or 12 ounces of fine gold to the ton, and silver in more variable quantities, though, usually, in the proportion of two ounces of silver for one of gold, and sometimes very much more.

In the smelting process, the purpose of which is to separate the copper, and with it the gold and silver, from the earthy gangue, the sulphur plays an important part, since the desired ultimate result of the successive chemical reactions in the furnace is to obtain the copper in the form of sulphide, while a portion of the iron and other foreign elements are removed in the form of slag. An excess of sulphur in the melted charge is to be avoided, because, in such case, the matt produced will be made poor by the presence of too much iron. A lack of sulphur, on the other hand, involves a loss of copper, since in the absence of a sufficient proportion of sulphur the copper becomes scorified or taken up in the slag. The first step, therefore, in the treatment of the ores is to subject them to a roasting process, by which means a portion of the sulphur is expelled and a partial oxidation of the metals effected. If the roasting should be carried too far, the evil can be remedied by the addition of raw ore in mixing the charge for the smelting furnace.

The proper mixture of the charge demands much practical knowledge of the processes involved and an intimate acquaintance with the character of the material to be treated, in order to adjust the proportions of the various elements to each other so as to effect the desired combinations and to insure other conditions, such as the formation of a liquid slag that may be distinctly separated from the heavier matt; since if the slag be thick, or not sufficiently

fluid, it will carry particles of the matt suspended in it, involving a loss of metal and the necessity of repeated fusion.

The principal operations at the works consist in the preliminary preparation of the ores, such as the breaking, weighing, sampling, and assaying of the various lots or parcels as they are delivered for treatment; roasting, which, in the case of hand-broken ores, is done in heaps in the open air, while tailings, the product of crushing in stamps, are roasted in furnaces; crushing, in rollers, of the roasted ore; smelting, for the production of matt, and the final crushing, packing, and shipment of the latter.

The ore, when first received at the yard, is deposited on a breaking-floor, where it is broken by hand to the size of a man's fist, or something less. Being thus prepared for the roasting heap, it is very carefully sampled for assay. The method of obtaining a sample, which shall fairly represent the whole mass, is as follows: The ore, in order to be removed to the roasting heap, is shoveled into barrows, each of which is capable of containing 200 pounds, and standing balanced on a scale. From each barrow, or, in some cases, from each alternate barrow, a shovelful is taken out and laid aside for sampling. When any given parcel of ore has thus been broken and weighed, the accumulated samples are taken together and reduced in size sufficiently to pass through a No. 4 screen—that is, a screen having four meshes to the lineal inch. The pile, having passed through this screen, is arranged in a conical form, divided into four quarters, of which two diagonally opposite quarters are taken, reduced still further in size so as to pass through a No. 8 screen. The operation of quartering and further reducing is repeated so that the material will pass through a No. 20, and subsequently, in similar manner, through a No. 40 screen, from which a final sample is taken, reduced so as to pass through a No. 80 sieve, and then assayed. By the assay of this sample, the value of the gold, silver, and copper contained in the ore is determined, and, in accordance therewith, the amount to be paid for the parcel is fixed by the established scale of prices, given on a following page.

In shoveling the ore into barrows, for the purpose of wheeling it to the roasting yard, it is thrown on a screen, by means of which the finer portion is separated from the coarse pieces, the former being reserved for covering the latter when laid up in heaps for roasting.

The roasting of the ore in heaps, or mounds, is a slow but comparatively cheap process. A single heap usually contains some 30 or 40 tons of ore and requires five or six weeks for the operation. In preparing it, a bed of cordwood, about 16 feet square, is laid as the base of the pyramid that is to be composed of ore. Directly upon the ground a course of thick billets of wood is laid, the sticks being parallel, but at a little distance apart, so as to permit the passage of a current of air. Above this, other courses of wood are laid more closely and crosswise, forming a bed about 5 or 6 inches thick, requiring altogether about a cord of wood for a single heap. A wooden chimney, or box flue, 9 or 10 inches square, is set up vertically in the center, passing down through the bed of fuel and reaching above the top of the heap. A small quantity of charcoal is put in at the bottom of this box or chimney, and the heap is ignited, when ready, by setting fire to the coal. The ore is formed into a heap about 4 or 5 feet high on this foundation and around the central chimney. The larger pieces are placed on the inside and the whole covered on the outside by a layer of fine stuff. This is so disposed as to control the rate of combustion, promoting it, if too slow in any part, by opening a passage for the draught, or checking it, if too rapid, by covering more closely. The heaps, when burning, require only sufficient attention to insure a proper rate. If allowed to burn too rapidly, the ore slags; or, if too slowly, the calcination is imperfect and the fire may go out altogether, requiring rehandling, with a loss of time and money. To break the ore, weigh it, wheel it to the yard, and lay it up in heaps, costs $2 30 per ton.

Tailings, owing to their fine condition, cannot be roasted in heaps, and must be treated in calcining furnaces, of which there are two. They are about 30 feet long by 10 feet wide, inside. The fireplace, separated from the hearth by a bridge about 15 inches high, is at one end of the furnace; the flue at the other end. The bottom of each is flat, and is a single course of common brick laid on a solid stone or rubble foundation. It is laid as three hearths, on slightly different levels; the first, about one-third of the total length, and most remote from the fireplace, is about 4 inches higher than the middle, which, in turn, is about 4 inches higher than the remainder, next the fireplace. The sides of the furnace are little less than 2 feet high, and the top is slightly arched over from side to side. In one side of the

furnace are six small doors through which the charge is introduced and stirred while in the furnace. The charge being put in at the end most remote from the fireplace, is gradually heated on the highest hearth, and, as the charges preceding it are advanced, it is moved on to the next hearth, making room for a new one, and so on, until on the third or lowest hearth, next the bridge, it is subjected to the highest heat. Each charge consists of one ton to a ton and a half of material, and three charges are put in during twenty-four hours, each charge remaining on each hearth nearly three hours. While in the furnace the charge is constantly stirred. Two men are required on each shift for each furnace; and one cord of wood is consumed in twenty-four hours. The capacity of each furnace is from three and one-half to four tons per day. The costs of treatment are said to be $5 per ton.[1]

The hand-broken ore, after being roasted or calcined, is prepared for the smelting furnace by crushing. This is done by Cornish rollers, of which there is a single pair; the rollers are 26 inches in diameter. In the crushing-house is also a Dodge crusher, for preliminary crushing of the larger pieces, chiefly used for breaking up matt that is of too low grade for shipment, and which, consequently, has to be subjected to a second smelting. After passing through the rollers, the crushed product falls upon a No. 4 screen, that which is fine enough to go through being carried to the smelting furnace, while the coarser portion is returned to the rollers.

The material, ores and tailings, having been calcined and crushed to the desired fineness, is then ready for the smelting furnace. This is a reverberatory, and resembles the melting furnace generally used in England for copper smelting. The foundation of the furnace is of solid stone, with a vaulted space under the hearth. The latter is 14 feet long by 9½ wide, inside; oval in shape or horizontal section, the smaller end being near the stack. The fire grate, at the opposite end, is 5 feet by 4, separated from the hearth by a bridge, 18 inches high. The arch is 18 inches high above the bridge, and slopes toward the opposite end, its mean height above the hearth being about two feet.

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[1] In addition to the calcining furnaces just described, there are two Gerstenhofer furnaces, designed for the same purpose. These furnaces, however, have not yet been operated satisfactorily, owing, it is said, to the poor quality of the fire-brick employed in their construction.

The working or skimming door, for the removal of the slag, is at the end near the stack, which latter stands at the corner of the structure, connected by a flue with the interior of the furnace. The skimming plate, which forms the sill of the door, is of cast iron, 9 inches thick and 8 or 9 feet long. In one side of the furnace is the feeding door, and on the opposite side is the tap. The bottom is slightly concave, or sloping toward the tap. The concavity is but a few inches below the skimming plate. The bottom is made by first laying, upon the prepared foundation, a flat floor of fire-brick, about two feet below the surface of the hearth. This is covered with a layer of finely-pounded flint, which, after being strongly heated during several days, is again pounded, and then covered by another layer of same material, mixed with slag. The sides of the furnace are 12 inches thick; the top is one course of brick, set on end. The whole structure is tied together by means of timbers connected by iron rods. The stack is 54 feet high, having a section at top of 27 inches square, increasing slightly toward the bottom.

The charge, weighing about two tons, is composed of different grades of calcined ores and tailings, with, sometimes, a little raw ore, or some rich slags of previous melting, so mixed as to adjust to each other the proportions of silica, iron, copper, sulphur, and other component parts, as may be desired. No other material is usually mixed with it. Six or seven hours, and sometimes more, are required for the smelting of each charge. When finished, the slag is drawn out through the skimming door by means of iron rakes, and is cast in sand molds of convenient size for handling. These are broken up and carefully inspected, as a certain portion on the bottom usually carries some particles of matt with it, and must be remelted; that which is sufficiently poor is thrown away. The matt resulting from the charge remains in the furnace, and another charge is introduced to increase the quantity of matt or metal, which is usually tapped off after about a ton has accumulated; it is finally drawn off through the tap, and cast in sand molds. If not sufficiently rich for shipment, it is broken up, and the concentration carried still further by repeated smelting. Usually from four to five charges, or from eight to ten tons of ore, produce one ton of matt. Under favorable conditions each furnace may yield one ton of matt per day, but it is not commonly quite so much. This matt, if made from the best ore, is rich enough to ship after the first melting, but the

greater portion of it is not brought up to the required standard without remelting. Under existing conditions it is desirable to produce for shipment a matt that contains about 50 per cent. of copper, with 40 or 50 ounces of fine gold, and between 100 and 200 ounces of fine silver to the ton. The loss in smelting for the production of matt is said not to exceed 5 per cent. of the assay value of the ore.

Each furnace is in operation night and day, and requires two men constantly, and four when charging the ore. It consumes from 10 to 12 cords of wood per day, which costs $6 per cord. A full and detailed statement of the costs of producing matt for shipment is not in the writer's possession. The matt, being concentrated to the desired quality, is then broken in the crusher and passed through the rollers; then packed in small sacks of stout canvas, sewed up, and shipped to Vivian & Company, of Swansea. The costs of packages, handling, freight, commissions, &c., not including anything of the cost of treatment after arrival, are stated at about $120 per ton of matt, which, per ton of ore, will depend on the degree of concentration which the matt represents.

It has already been said that the proprietors of the Smelting Works purchase their supplies of ore from the miners, or producers. The following paragraph contains the scale of prices, according to which such purchases are generally made. The schedule is not invariably adhered to, but is modified occasionally according to the peculiar character of a given parcel of ore, or to suit extraordinary conditions. It serves, however, as a general basis of calculation.[1]

The scale is graduated according to the number of ounces of fine gold contained in the ton, or 2,000 pounds, of the ore. Thus, for ores containing any number of ounces, as expressed in the left-hand column following, the price paid is the corresponding percentage, expressed in the right hand column, of the value of the gold and the copper contained.

[1] Intelligence lately received from Colorado is to the effect that the prices paid for ores, since January 1, 1870, are higher than those indicated in the scale here given.

| Ounces of fine gold, per ton of 2,000 pounds. | Percentage paid of the value of the gold and copper. |
|---|---|
| 10 | 60 |
| 9 | 58 |
| 8 | 55 |
| 7 | $52\frac{1}{2}$ |
| 6 | 50 |
| 5 | 45 |
| 4 | 40 |
| 3 | 30 |
| 2 | 20 |

In calculating the value of ore, according to the above scale, the ounce of fine gold is reckoned at $20, coin, and the unit of copper at $2. The copper unit, however, is to be reckoned on the English ton, and as the ores are assayed and purchased by the short ton, a deduction of 12 per cent. is made on the copper assay. Thus, if an ore is found to contain 8 per cent. or units of copper, worth, according to the above scale, $16, a deduction of 12 per cent. is made to adapt it to the English ton. Moreover, the copper is determined by wet assay, from which $1\frac{1}{2}$ per cent. is to be deducted for working loss, so that, if the percentage of copper contained in an ore does not exceed $1\frac{1}{2}$, no account is made of it in estimating its value.

In addition to the above, the silver is paid for at the rate of 75 cents per ounce, after deducting from the number of ounces contained per ton as many ounces as there are units of copper, a rule said to be enforced at the Swansea works. These values are all in coin; they are paid in currency, allowing the premium that rules at Central City on the day of settlement, usually 4 per cent. below the rate at New York.

As the great bulk of ores produced from the veins about Central City are essentially gold-bearing, these Smelting Works have comparatively little occasion to treat true silver ores; or such as are chiefly valuable for their silver, and carrying little or no gold. The proportion of this class of ore has increased, however, of late, especially since the discovery of rich silver-bearing veins, a mile or thereabouts below Black Hawk, in the neighborhood of Slaughter-house Gulch, and it is reported that a furnace, specially designed

for their treatment, will soon be built. Such ores are purchased at the works according to an established scale of prices, which, as it does not differ much from a similar schedule fixed by the Georgetown Smelting Works, and given in the following chapter, need not be repeated here.

The following table, prepared from data furnished by Professor Hill, shows the average contents, in gold, silver, and copper, of various lots of ore produced from different mines, and sold for smelting:

| From what lode. | From what mine. | Number of tons. | Average number of ounces of fine gold per ton. | Average number of ounces of fine silver per ton. | Average percentage of copper after deducting 1½ per cent. |
|---|---|---|---|---|---|
| Bobtail | Bobtail | 464 | 4.78 | 8.00 | 6.37 |
| Bobtail | Black Hawk | 11 | 5.25 | 7.00 | 7.50 |
| Bobtail | Trust | 65 | 5.10 | 7.50 | 2.50 |
| Bobtail | Sensenderfer | 2 | 11.00 | 15.00 | 10.50 |
| Bobtail | Sterling | 146 | 5.82 | 6.65 | 5.70 |
| Fiske | Sterling | 12 | 5.00 | 7.00 | 9.30 |
| Gregory | Narragansett | 18 | 2.25 | 7.00 | 9.00 |
| Gregory | Gregory Consolidated | 8 | 4.25 | 10.00 | 3.50 |
| Gregory | Briggs | 136 | 5.25 | 10.50 | |
| Gregory | Smith & Parmelee | 28 | 3.46 | 12.00 | |
| Bates-Hunter | - - - - - - - - - | 12 | 3.25 | 10.00 | 2.00 |
| Burroughs | Ophir | 230 | 4.85 | 10.00 | |
| Burroughs | Gilpin | 178 | 4.25 | 8.50 | |
| Burroughs | First National | 20 | 3.75 | 9.00 | |
| Gardner | Clark | 38 | 3.84 | 11.26 | |
| Illinois | North Star | 65 | 3.25 | 15.50 | |
| California | Stalker's | 424 | 2.89 | 18.00 | |
| Coaley | Coaley | 73 | - - | 215.00 | |
| Veto | - - - - - - - - - | 31 | - - | 270.00 | |
| Prize | - - - - - - - - - | 95 | 2.00 | 25.00 | |

The works of the Boston and Colorado Smelting Company were built during the summer of 1867, and begun smelting operations in February, 1868. Since that time their capacity has been largely increased, and, during the past year, was quite equal to, if not a little in excess of, the supply of ore. They

are managed by skillful and experienced men, and, it is said, have been profitably conducted. The establishment has been and is of great advantage to the district, affording, as it does, the best and almost the only suitable method of treatment that has yet been introduced for the first-class ores.

The first shipment of matt was made from these works in June, 1868. A complete statement of the shipments since that time is not in the writer's hands, but from available data may be estimated at about 25 tons of matt per month, containing, on the average, 40 ounces of fine gold, 200 ounces of fine silver, and 40 per cent. or 800 pounds of metallic copper, per ton. This is equal to 1,000 ounces of gold, 5,000 ounces of silver, and 20,000 pounds of copper, per month. The *gross value* of these metals, thus shipped, is about $30,000, coin, per month, or $570,000 from date of beginning to January 1, 1870.

Chlorination Works.—These works were established in this district in 1868, by Mr. Cash, a gentleman who had already had a considerable experience at Grass Valley, in California, in the treatment of auriferous pyrites by the chlorination process. It is the purpose of this process to extract the gold by first converting it from the form in which it exists in the ore into that of the soluble chloride, obtaining this in an aqueous solution, and then precipitating the gold, in the metallic state, by the sulphate of iron. This process has been successfully employed in Europe during many years, and was introduced in California about ten years ago, where it has given great satisfaction. It was brought to Colorado by Mr. Cash with the purpose of treating tailings, but owing to various hinderances had not entered upon regular operations at the date of the writer's visit in 1869. One cause of this delay is said to be the low value of the material to be treated, the tailings having been formerly supposed to be much richer than now appears to be the case. It is now reported that the establishment will be provided with some suitable crushing machinery and be employed in the treatment of first-class ores. The works consist of one reverberatory furnace in which the ores are subjected to a chloridizing roasting; four large chlorination vats, or tubs, in which the roasted material is subjected to the action of the chlorine gas; the necessary apparatus for generating chlorine; two precipitation tubs, in which the gold is thrown down by sulphate of iron; and a small melting furnace, for running the metallic

gold into ingots. The present capacity of the works is about three tons per day. For a full description of the chlorination process, the reader is referred to Guido Küstel's "Concentration and Chlorination."

The California Reduction Works, another establishment designed for the working of high-grade ores, especially those rich in silver, are situated near Black Hawk. They have not been in constant or regular operation during the past year or two. The process employed is that of chloridizing roasting, performed in a Brückner cylinder, and subsequent amalgamation in barrels. This is essentially the same as that which is in use at Georgetown, and noticed with more detail in the next chapter.

Production of Gilpin County.—The total value of the bullion produced in Gilpin County during the past two years may be very nearly ascertained by adding to the aggregate shipments of the three banks of Central City the value of the matt shipped from the Boston and Colorado Smelting Works. Nearly all the bullion produced in the county is shipped in one or the other of these two forms; the crude bullion, obtained in the stamping-mills, being either sold to the bankers or shipped through them; while the value of the first-class ore is represented in the matt. The amount that leaves this part of the country in private hands, or by other means than those just indicated, is thought to be insignificant by those who are very competent to judge.

A record of the bank shipments, during the period referred to, has been very carefully kept by Mr. Frank C. Young, cashier in the banking-house of Warren Hussey & Co. The following is Mr. Young's statement, showing the coin value of the aggregate shipments of the three banks at Central City during the years 1868 and 1869:

| Month. | 1868. | 1869. |
|---|---|---|
| January | $80,000 | $77,000 |
| February | 95,600 | 85,800 |
| March | 75,000 | 101,700 |
| April | 79,000 | 108,000 |
| May | 104,000 | 116,000 |
| June | 106,000 | 147,000 |
| July | 101,000 | 124,000 |
| August | 113,700 | 161,500 |
| September | 85,000 | 122,000 |
| October | 113,000 | 110,000 |
| November | 114,500 | 120,500 |
| December | 108,200 | 106,500 |
| | 1,175,000 | 1,380,000 |
| Currency value | $1,648,550 | $1,835,975 |

| | | |
|---|---|---|
| Total coin value of gold shipments from the banks during two years | | $2,555,000 |
| The gross coin value of the gold, silver, and copper contained in the matt shipped from the Boston and Colorado Smelting Works, during the same period, may be estimated as follows, in accordance with a statement on a foregoing page: | | |
| Gold | $390,000 | |
| Silver | 123,000 | |
| Copper | 57,000 | |
| | | 570,000 |
| Total coin value produced and shipped in 1868 and 1869 | | 3,125,000 |

The above statement makes no allowance for undervaluation of bankers' shipments, amounting to five or ten per cent. In the estimate of the total bullion production of the Territory, given on a foregoing page, this element is taken into account.

# CHAPTER X.

## SILVER MINING IN COLORADO.



## SECTION I.

### GEORGETOWN MINES.

The most productive silver-mining district in Colorado, at the present day, is that of which Georgetown is the center. Indications of its mineral wealth were discovered in 1859, but the developments then made were not very extensive. During several years following the district was prospected by a few parties, but it was not until about 1866 or 1867 that the mining enterprise of the region began to assume the importance which it now possesses. About that time new and valuable discoveries were made which gave a fresh incentive to exploration; many veins of more or less value were opened and prospected, a few of which have already proved to be productive and profitable mines, while many others, though less extensively worked, have afforded encouraging results. Metallurgical works of various sorts have since been erected, and are now steadily employed in the treatment of the ores; a town containing 1,500 or 2,000 inhabitants has been established and provided with good hotels, postal, telegraphic, and express offices, churches, schools, and other essentials of civilization; the mines are being persistently developed, and the value and importance of the region appear to be steadily, if not rapidly, increasing.

The district is located in the elevated portion of the mountain range, on the southern and upper tributaries of South Clear Creek. Georgetown is situated at the confluence of two beautiful mountain streams, which, descending from the crest of the range, through deep and sharply-cut ravines, to their point of junction, unite there to form the South Branch of South Clear Creek, which flows thence in a northerly and easterly direction, about four miles, where it joins the main stream known as South Clear Creek, at a point about four miles below the town of Empire. Thence the stream flows on in an easterly direction, fifteen miles, to its junction with North Clear Creek, a point still in the elevated mountain region, and twelve or fourteen miles from the foot-hills. Thence, as Clear Creek, and by this time a respectable mountain river, it flows on, emerging from the foot-hills at Golden City and emptying into the South Platte, a few miles below Denver.

The country about Georgetown is of an exceedingly rugged, mountainous character. The town itself is over 8,000 feet above the sea. The valley, from the fork of the stream, where Georgetown is situated, to its junction with South Clear Creek, is narrow and deeply cut. Near the town it is from 500 to 1,000 feet wide from the base of the hills, on one side, to that on the opposite side, and its comparatively level bed affords a favorable site for settlement. The mountains rise very abruptly, almost precipitously in places, to the height of 1,200 or 1,500 feet above the stream. Although very rocky, their sides are partly covered by timber. Ascending either fork of the stream, above the town, the observer finds a narrow valley, on either side of which the mountains rise steeply 1,500 or 2,000 feet high, cut here and there by sharp lateral ravines. Between the forks of the stream, Burrell Mountain rises directly behind and south of the town; the crest of the spur, of which this mountain forms the end, turns to the westward, ascending toward the summit of the main range, its successive peaks or higher points beyond Burrell Mountain being locally known as Leavenworth, Pendleton, and McClellan Mountains. On the north side of the right-hand fork, which has an east and west course for three or four miles above the town, is Sherman or Republican Mountain, and beyond that, further west, and separated from it by a narrow ravine, is Brown Mountain.

Below the town the mountains are locally termed, on the left hand or

west side of the stream, Democrat, Columbia or Colfax, and Douglass Mountains, the latter being at the confluence of the south branch with South Clear Creek. On the opposite or eastern side of the valley, a half-mile below the town, is Griffith and Summit Mountains. In all these hills, and in others adjacent, whose names have not been mentioned, the work of exploration has been carried on, and, in some cases, attended with very important results.

The Veins.—The veins of the Georgetown district are highly argentiferous, but they contain little or no gold. Some of them are reported to be slightly gold-bearing, but so far as the writer's observation extends, the typical veins of the region have no gold whatever. The country-rock is generally granite and gneiss, presenting many lithological and mineralogical varieties. The prevailing character is, perhaps, gneissic, but many varieties of structure and mineral composition occur in close proximity to each other, and sudden and frequent transitions from one form to another may be observed throughout the district.

The veins, generally, are not very wide. Like the gold-bearing lodes of Gilpin County, they present among themselves a striking similarity in course and dip; and, further, the prevailing direction is very nearly the same as that of the veins about Central City. With rare exceptions, the course of veins, observed by the writer in this district, is between due east and west, on one hand, and north 55° east on the other. The last named course, itself somewhat exceptional, is that of the Equator, one of the most prominent lodes of the district. The Terrible, another of the most distinguished veins, strikes north 77° east, while the majority of veins, less developed than those first named, have a course of due east and west. In this statement the true course is spoken of, allowing about 15° easterly variation in the magnetic course. The veins dip generally at a high angle, in many cases vertically. Like those of Gilpin County, they are regular, well-defined fissures, and are not faulted. Their other natural features, the character of the gangue and ore, and the mode of occurrence and value of the silver-bearing and other associated minerals, will be more fully shown in the following description of some of the best developed and most important examples.

Terrible.—The Terrible mine is located on Brown Mountain. This mountain is one of those on the north side of the right-hand fork of the

stream above Georgetown, and is three miles distant from the town. The hillside rises very steeply from the bed of the valley. The lode on which the mine is located bears the same name; it crops out on the southern slope of the hill, several hundred, perhaps a thousand, feet above the stream at the base. It is said to be clearly traced for 2,000 or 3,000 feet along the hill-side, but it was discovered and has been chiefly developed in the immediate neighborhood and on the west side of the ravine that divides Brown Mountain from Sherman Mountain.

On Plate XXXV will be found a longitudinal section of the mine, which represents the extent of the work that had been accomplished at the end of August, 1869. The following are some of the results that appear from these developments.

The course of the lode is 62° east of magnetic north, or about 77° east of true north, coinciding nearly with the trend of the hill. Its dip is vertical to the depth of 80 feet, where it inclines slightly to the north at an angle of 75° from the horizon. The width of the vein is from 1 to 5 feet. The country-rock, where observed by the writer, is a close-grained granite, containing reddish feldspar and a fine black mica. The walls are very well defined; they frequently show polished and striated surfaces and are usually separated from the main filling of the fissure by selvages of clay an inch or two in thickness. The filling of the vein consists usually of an ore-seam which is from 2 to 14 inches thick, averaging about 8 inches, and with this is associated a gangue rock of somewhat varied character. The gangue, apparently most intimately associated with the ore, is a mixture of quartz and feldspar, the latter being sometimes in coarse particles. Sometimes this material is talcose and finely laminated. Gangue of this character almost always, if not invariably, accompanies the ore, frequently occupying the space between the several seams of pay-mineral. In other parts of the vein, and often closely associated with the foregoing, the vein-rock appears to be composed of quartz, feldspar, and mica, presenting the appearance of true granite. These two kinds of gangue rock sometimes occur separately, sometimes together; in the latter case there is usually a marked difference in their appearance, hardness, color, and mineral composition, which suggests that they are of different age or origin.

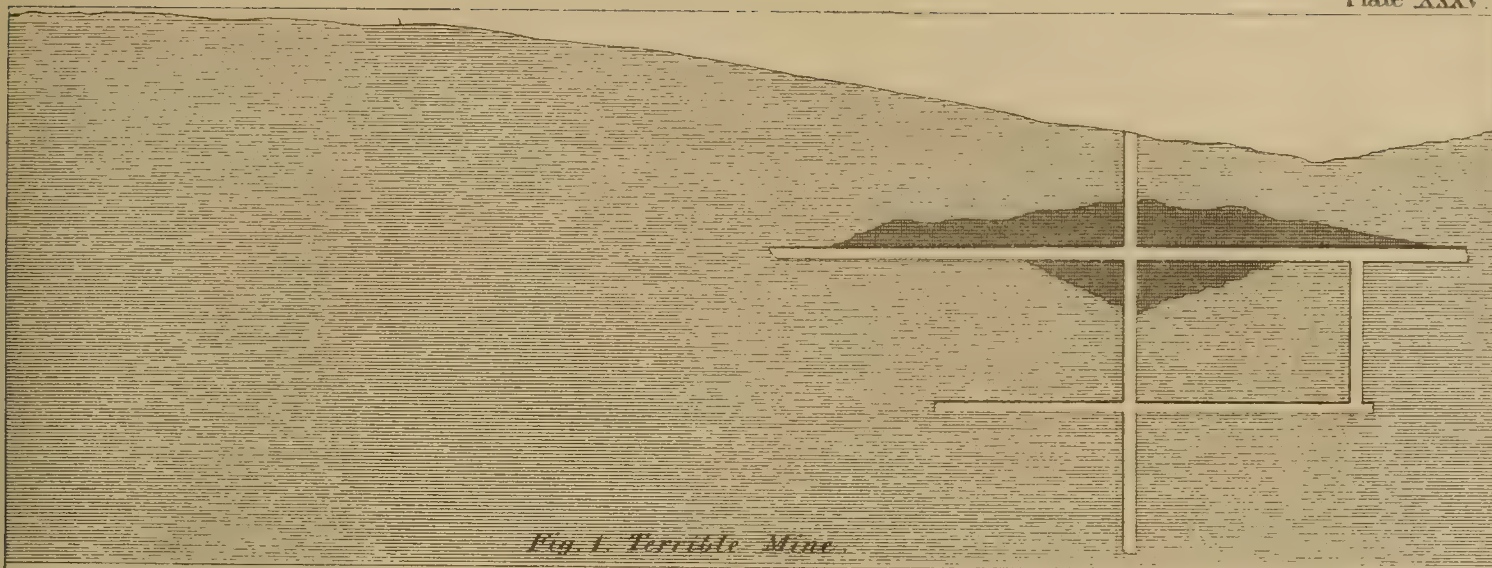
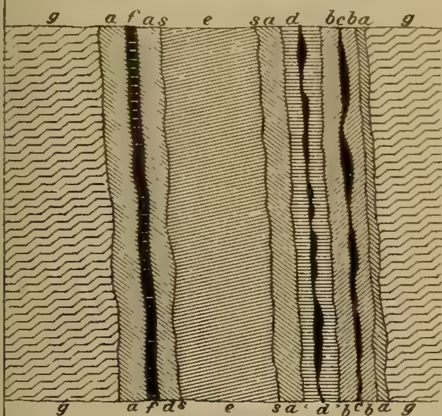


Fig. 1. Terrible Mine.




## Fig. 2.

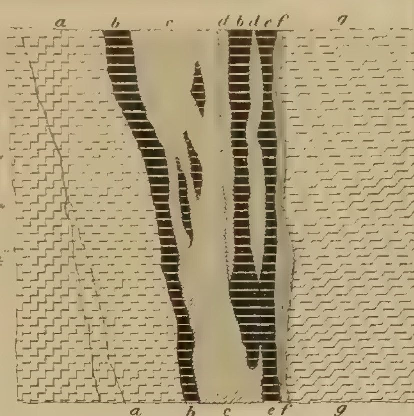
a. Gangue rock.
b. Chiefly pyrites, with some fahlerz and blende 2" a 4"
c. Coarse grained galena 2"
d. Galena, blende, pyrites and some silver ores 6" a 8"
e. Newer gangue rock, containing quartz fragments 24"
s. Dividing seam of clay.
f. Solid seam, like b, rich in silver ores 2"
g. Country granite.

Scale: $\frac{1}{30}$.

## Fig. 3.

a. Gangue rock, quartzose and felspathic matter.
b. Zincblende with some galena and rich silver minerals 3 @ 5"
c. Vein matter, mixed with streaks of ore 6 @ 15"
d. Seams of clay and broken vein matter 2 @ 4"
e. Chiefly galena with blende.
f. Clay selvage on wall.
g. Country granite.

Scale: $\frac{1}{30}$.



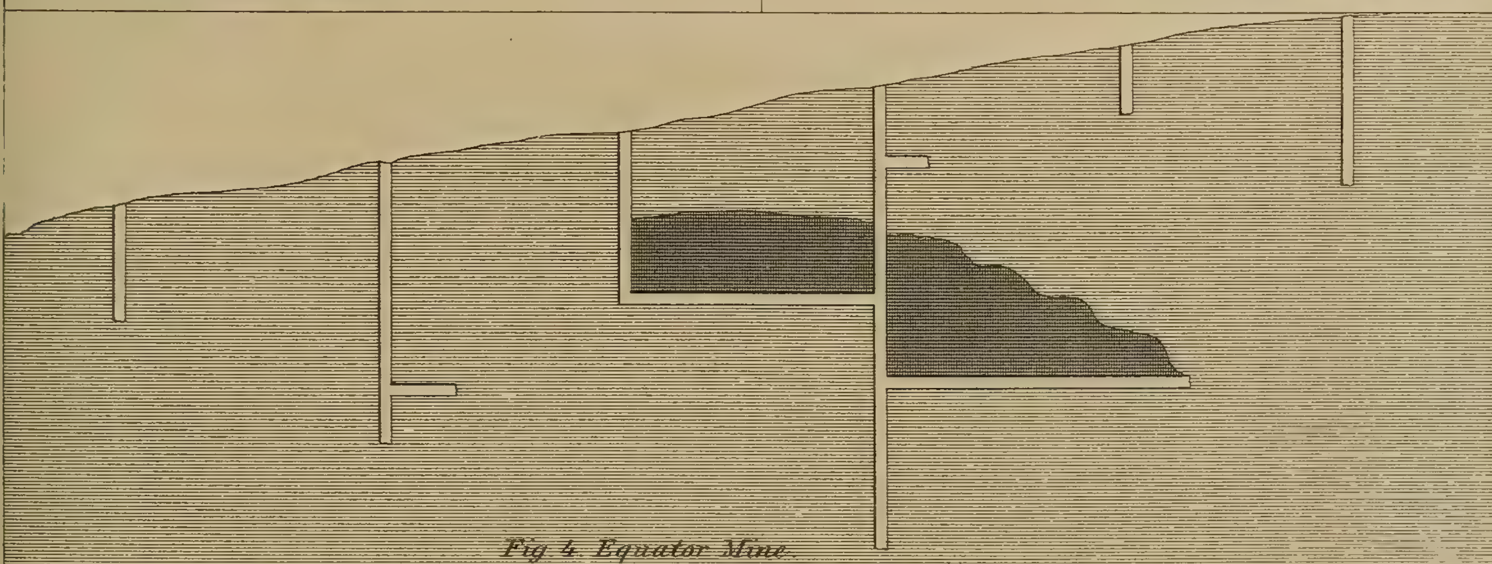



Fig. 4. Equator Mine.

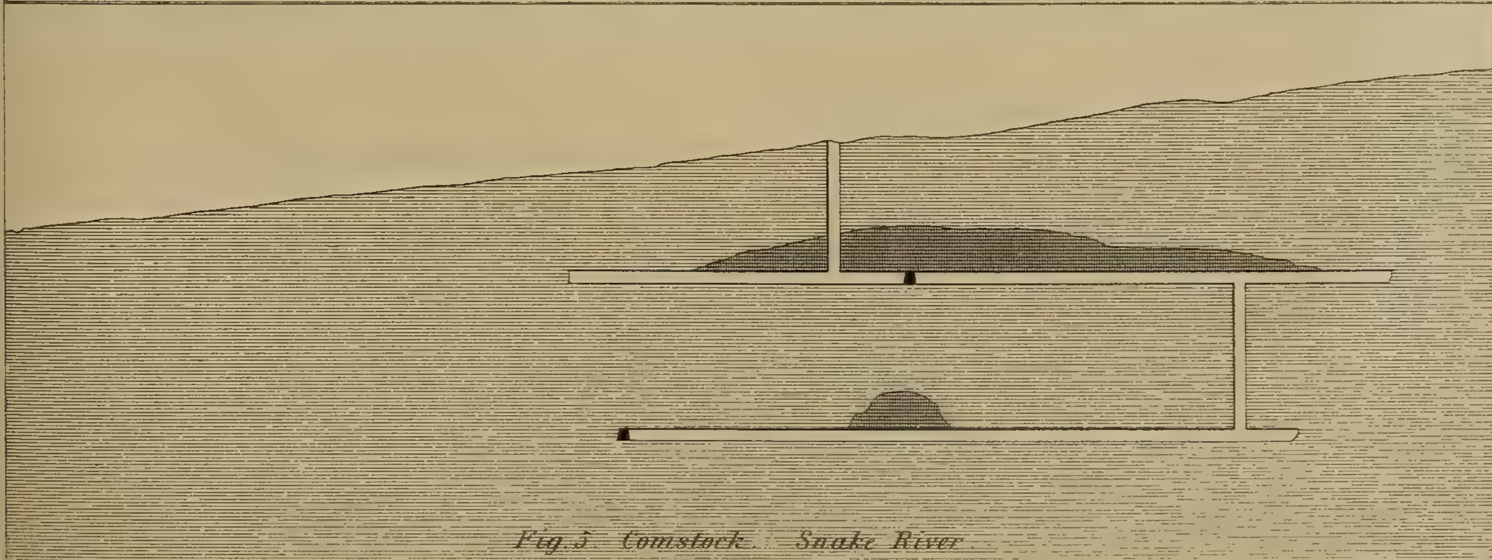


Fig. 5. Comstock. Snake River.

Scale: $\frac{1}{1200}$.

The ore consists chiefly of galena and zincblende with some iron and copper pyrites; with these are associated some rich silver minerals, comprising stephanite, silver glance, fahlerz, some native silver, and, occasionally, ruby silver. The galena is thought to be quite rich in silver, which may also be true of the zincblende, but the great value of the ore is probably due to the abundant occurrence of true silver minerals. The gangue mineral most frequently found with those just named is crystallized quartz, with which are associated fluor spar, heavy spar, and others in small proportions.

The ore-seam, where seen by the writer, was generally compact, occurring sometimes on the south wall and sometimes on the north wall of the vein. Occasionally, however, it is split up, forming a number of parallel seams. A narrow selvage of clay divides it from the wall of the vein, and sometimes from the accompanying belt of gangue rock. The minerals composing the seam are often crystallized, and vugs, or cavities with crystalline linings, are frequently met with.

Fig. 2, on Plate XXXV, represents a transverse section of this vein at a point observed and sketched by Professor Schirmer, an educated mining engineer, formerly residing at Georgetown and connected with the Terrible mine. The alternating seams of ore and accompanying gangue are clearly shown. According to the view of Mr. Schirmer, who has had occasion to study closely the formation of this vein, the middle mass of gangue rock, *e*, is of later origin than the other material on either side, having intruded itself into the vein, widening the fissure, and producing the slickensides, or polished surfaces, that may be observed on the planes of contact between it and the older rock, *a*. This view is also supported by the occurrence, in the supposed newer rock, of imbedded fragments of quartz several inches thick.

Fig. 3, on same Plate, is a somewhat similar section, taken in the Brown lode, a vein occurring near the Terrible; but in this case the differences between the masses of gangue rock are less clearly distinguished.

The value of the ore may be best shown by the following statement. The developments made in the mine comprise the sinking of the main shaft, 185 feet deep; the driving of the three levels shown in the section, the upper one being 310 feet in length, and the stoping, which is also indicated. The whole extent of ground stoped, at the time referred to, was 60 or 70 fathoms.

From this work were produced[1] 98 tons of ore that yielded $560, coin, per ton; 29 tons shipped, or ready for shipment, to Newark, having an average assay value of $642, coin, per ton, but from which the returns of actual yield had not been received; 68 tons of second-class ore, of which 48 tons, worked, yielded $210, coin, per ton; besides which, it is said, there are from 1,200 to 1,600 tons of third-class ore on hand, consisting of inferior quality of vein-matter mixed with small particles of rich ore, broken in the mine and on the assorting floor, the whole of which is estimated to contain, by assay, $80 to $100 per ton. This material must be concentrated before treatment.

This mine was discovered in the winter of 1866–'67, and has been developed gradually by a small force on a careful and economical basis. The original outlay of capital is said to have been small, and the profits of the work considerable, but the writer has no direct information on that point. The costs of mining cannot be very closely estimated from the available data. Sinking costs $40, currency, per foot; drifting, $20 per foot; stoping, $40 per fathom. The mine is provided, at the mouth of the shaft, with a small engine for hoisting and pumping. The pump is small and the water abundant, and, for this reason, the work, in the lower part of the mine, was suspended during the summer of 1869, awaiting the completion of a tunnel, then being driven in from the hill-side. The steep slope of the hill affords great advantages for attacking the lode by tunnels, and this is now being done. An adit, about 350 feet long, strikes the vein at a depth of 260 feet, dispensing with the necessity, for some time to come, of raising either rock or water. The outcrop of the vein being several hundred or a thousand feet above the valley, it may be worked by this means to a very considerable depth.

The tunnel referred to is 6½ feet wide by 7½ feet high. It passes through very hard granite. It is driven with the aid of the Burleigh drill, which gives great satisfaction, performing its work at half the cost of hand labor, according to the estimate of the owners of the mine. The whole working cost of driving this tunnel had been, at the time referred to, about $40 per foot. Several other tunnels are being driven in this district, some of which employ the Burleigh drill, and will be noticed further on. The following are a few notes

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[1] According to statement furnished by Mr. F. A. Clark, one of the owners and manager of the mine.

concerning the experience in this kind of work, in the tunnel just referred to, at the Terrible mine.

The air compressor of two cylinders, each 12 inches diameter and 16 inches long, only one of which is required for the present work, is set up at the mouth of the tunnel, and driven by an engine of 12 inches diameter. It is capable of running two drills, but only one is used. The drill is worked under a pressure of air of 35 to 40 pounds; strikes 300 blows per minute; the drill is $1\frac{1}{4}$ inch steel, with $1\frac{3}{4}$ inch bit; the progress of the drill in the hole averages 2 inches per minute; each drill, on the average, drives 30 inches before needing to be sharpened; the machine is managed, at the heading of the tunnel, by two men on each shift, who drill from six to eight holes per shift, including the time required for charging and firing, the latter being done by electricity, and for removing the broken rock; the force required at the tunnel comprises six men, four of whom are drillmen and two engineers, besides the smith, at the mine, who sharpens the drills. Labor costs $4 50 to $5 per day, for shift of twelve hours. The average progress of the tunnel is $1\frac{1}{2}$ feet per day of twenty-four hours. It is reported that the property of the Terrible mine has been recently sold in England for $500,000.

Brown.—Brown Mountain, on which the lode just described is located, has been extensively prospected, and a number of valuable veins have been opened. Among these the John Brown, U. S. Coin, Lilly, Roe, Mammoth, and others have been developed considerably, and have produced some very rich ore. The John Brown lode crops out on the hill-side, 300 or 400 feet above the Terrible. It has a nearly parallel course, north 75° east, and dips almost vertically, but slightly inclined to the south. The width of the vein is variable. Where both walls are clearly defined they appear to be from two to five feet apart; but the south wall is often difficult to distinguish, and as the filling of the vein is, to a large extent, granitic, or like the country-rock, it is not always easy to define their position. Where cross-cut in one or two places the vein is thought to be from 15 to 24 feet wide. The ore of this vein resembles that of the Terrible in most respects, but is characterized by the occurrence of much more zincblende. This is the predominating mineral, and is said to be argentiferous. With it is also mixed considerable galena, rich in silver, and a small proportion of pyrites, with true silver minerals. These are

stephanite, pyrargyrite, proustite, polybasite, fahlerz, antimonial silver, and native silver. The rich silver minerals seem to be less abundantly distributed in the Brown than in the ores of the Terrible, though some lots of selected ore have proved to be very rich. The ore is sometimes concentrated in one compact seam, lying upon one wall, or is sometimes divided into several branches. The width of the seam may be from 2 to 10 or 12 inches.

Fig. 3, on Plate XXXV, shows a cross section of this vein, observed by the writer, not far below the surface. The north wall is well defined, carrying seams of rich ore; the south wall is not so clearly identified, the left hand side being limited by the side of the drift, and the true character of the adjoining rock remaining undetermined. The mass of gangue rock here is a mixture of quartz and feldspar, much broken up, traversed by clefts and joints and colored by oxide of iron. The several seams of ore appear to unite at a point not far below that where the section was taken.

The mine has been opened by a tunnel, 180 feet long, through the country-rock, at a right angle to the vein, which it strikes at 160 feet below the surface. From this point of intersection a drift has been made, about 180 feet on the vein. A tunnel or adit, starting from a point about 100 feet higher than the drift just mentioned, has been driven in on the vein from its outcrop in the neighboring ravine, about 250 feet in length, and connected by winzes with the drift below. In connection with all this work considerable stoping has been done.

The company owning this mine have expended a large sum of money in the development of the property, chiefly, however, in the construction of metallurgical works and other appurtenances. As the mine is worked by tunnels, no hoisting machinery has been required, but a large and costly crushing mill and smelting furnaces have been built at the base of the hill, just below the mine. These works consist of 20 stamps, a Blake's rock breaker, some concentrating appliances, a roasting furnace, lead-smelting furnace, and cupelling furnace. Some details of the various methods of treatment applied to the ores of the district will be found further on. It will suffice to say here that the first-class ore is crushed without concentration, while the bulk of the mine product is reduced by stamps, concentrated in a round buddle, and the richer portion obtained for roasting and smelting. The ore of this lode is rather too poor in

lead for smelting alone, and that metal is usually supplied by purchasing galena elsewhere, which is then mixed with the material to be treated. According to Mr. Watson, superintendent of the mine, the greater part of the product of the mine is low-grade ore, requiring concentration. During the summer of 1869 there were 191 tons of mineral smelted at these works. The greater part of this was obtained by concentrating ores that, in the raw state, had an average value of 20 to 30 ounces of silver per ton. According to the average rate of concentration, six tons of raw ore furnish one ton of mineral. This being mixed with the first-class ore, the whole is subjected to the roasting and smelting process. The average assay value of the smelted mineral, during the period referred to, was 200 ounces of fine silver per ton, of which an average of 90 per cent. was obtained by metallurgical treatment. From this it appears that the product of the works, during the summer of 1869, was between $40,000 and $50,000.[1] The ore furnishing this yield came partly from the Brown and partly from the U. S. Coin lode. The latter is said to produce much richer ores than the Brown.

As the hill-side on which the mine is situated is too steep to admit easily of the construction of a wagon-road, the mine has been provided with a suspension tramway, the upper end of which is at the mouth of the tunnel and the lower end at the base of the hill. This contrivance consists of two wire ropes, each 1¼ inches in diameter, stretched side by side, 6 or 8 feet apart, elevated above the ground and supported at intervals of 200 or 300 feet. The ends of the ropes are securely anchored in the ground. The average inclination of the ropes, from the upper to the lower end of the tramway, is about 20°. Each rope serves as a separate track for the passage of a car, which is attached to a framework of iron; the latter hanging upon the rope, on which it rests by means of two sheaves or wheels, which, turning freely, permit the movement of the car along the rope.

The two cars are so arranged that one descends, carrying a load of ore, and, by its weight, draws up the other car, which may also carry a light load of supplies or material for the mine. A small wire rope, a half inch in diameter, connects the two cars, passing around a drum at the upper end of the

[1] According to statements made by Mr. Watson, superintendent, and Mr. Cheever, assistant.

tramway, which drum is controlled by a brake. The car is capable of containing about 1,000 pounds of ore. The details of construction, showing the method of supporting the cables in such way that the cars may pass, the form of the framework to which the car is attached, and the arrangement of the sheaves cannot be very intelligibly explained without drawings, which are not in the writer's possession. It is said to work satisfactorily.

COIN.—The U. S. Coin lode has been developed by the same company. It crops out a little higher up the hill and is opened further west than the Brown mine. Its course is nearly due east and west, the dip being almost vertical. The ore, in its mode of occurrence and general character, is like that of the Terrible and Brown lodes in most respects, but is usually concentrated in a narrow seam of rich mineral. Ruby silver is said to occur frequently. Small lots of ore from this lode have yielded very high returns.

LILLY AND ROE.—The Lilly and the J. J. Roe, though different locations, are thought to be on one and the same vein. This is still higher up the hill than the last-named. Its course, where observed, is north 55° east, true, dipping to the south at an angle of 80° from the horizon. This lode has also produced rich ores, similar, in general character, to those just described. In 1868 two tons of selected ore yielded $400, coin, per ton. The lower grade ore, treated at the amalgamation works in Georgetown, yielded about $150, coin, per ton, for a lot of 44 tons. The developments on this lode have been considerable as compared with other lodes in the neighborhood, but have not yet reached great depth. When seen by the writer the deepest point attained was not more than 100 feet. The vein had been stripped along the surface but not drifted upon very extensively in depth.

SHERMAN MOUNTAIN.—Sherman Mountain, as it is called by some, or Republican Mountain, by others, is next east of Brown Mountain, from which it is divided by a narrow gorge or ravine. This hill has also been extensively prospected and many lodes have been opened, though only a few have been developed to a depth exceeding 100 feet. They are generally of the same type as those just described. Prominent among them are the Cashier, Mendota, Snowdrift, Robert Emmet, Bush, Huntington, and others. The first-named is thought to be an extension of the Terrible, though its identity could not be established from observations made at the time these notes were

taken. A shaft has been sunk on this vein to the depth of 62 feet, showing an ore-seam 8 or 10 inches wide. The ore at this depth is chiefly zincblende, but carrying the other minerals already mentioned as characteristic of the lodes on Brown Mountain. Some of the ore has a high assay value, but not much has been worked. The course of the vein is north 80° east, true, dipping almost vertically.

BAKER.—The mountain slopes, bordering the right hand fork of the stream above Georgetown, have been explored, more or less, along their entire length Three or four miles above Brown Mountain, and about seven miles from Georgetown, Kelso or Quail Creek enters the main fork from the south side. At this junction is situated the mill of the Baker Mining Company, a large and costly establishment. The mine of the same company is located four miles from that point, on the eastern slope of Kelso Mountain, near the head-waters of the stream. It is not far below the crest of the range, having, it is said, an altitude of over 11,000 feet, and being in the immediate neighborhood of Gray's Peak, which has an elevation of about 14,300 feet. The mine is probably more extensively opened than any in the Georgetown district, though, thus far, the vein has not been very productive. The general strike of the lode is about north 80° east, true, dipping northerly at an angle of 55° to 60° from the horizon. The width is variable, generally about 3 feet, but sometimes expanding to 15 feet, or more. The inclosing rock is granite or gneiss. The walls, particularly the south wall, are good and well defined. The vein-matter is generally a mixture of quartz and feldspar. It is usually soft and separated from the walls by a seam of clay. In some parts of the vein the filling is chiefly siliceous, and sometimes becomes a hard flinty substance, without showing much ore. The ore-seam is not continuous. So far as developed, when visited by the writer, the pay-mineral occurs in disconnected bunches, or pockets, and not very abundantly. The ore consists chiefly of galena, zincblende, and silver sulphurets. The associated gangue is mainly quartz, but in the lower levels an abundance of fluor spar is a characteristic occurrence. The mine has been opened by three tunnels or adits. The upper one, known as the Discovery tunnel, was, in the autumn of 1869, about 200 feet long, driven in upon the vein, having started at the outcrop; the two lower tunnels are partly in the country-rock and partly on the vein,

the middle tunnel being about 200 feet, and the third, or lowest, being over 400 feet in length. These adits are connected by winzes. The amount of stoping that had been done, at the date referred to, was comparatively small. From these openings small lots of selected ore had been obtained that had yielded from $200 to $300 per ton. The lower grade, or common ore, yielded from $50 to $100 per ton. Up to the date referred to no very large amount had been worked, as the company's mill had not then commenced operations. The total product of the ores treated is said to have amounted, at that time, to about $6,000; besides which about 200 tons of common ore were awaiting treatment in the company's mill. The construction of this establishment was begun early in 1868, but owing to changes of plan and other hinderances it was still unfinished in the autumn of 1869. The process at first selected was that of smelting with lead and subsequent cupellation, for which method the furnaces were built; but as the ore proved to contain a lower percentage of lead than is requisite, this was discarded and the chloridizing-roasting, with barrel amalgamation, was adopted. Some details of this method will be given further on. The mill consists of crushing machinery, which comprises one Dodge crusher and two Ball pulverizers; three of Brückner's revolving cylinders for chloridizing-roasting; six barrels for amalgamation; a retorting furnace, and other appurtenances necessary for the business, including two excellent steam-engines, the cylinders of which are 14 inches by 30, geared together to drive all the machinery. Two large boilers supply steam.

The left-hand fork of the stream above Georgetown has been as actively explored, at least for a portion of its length, as the right-hand fork. The course of this stream, from its head-waters to its confluence with the other fork at Georgetown, is generally from the southwest to the northeast. The principal mining developments have been made in the hills which rise between the two streams. Of these hills, that which is known as Leavenworth Mountain has, thus far, been the scene of the most active operations.

Equator.—The Equator mine, on a lode of the same name, is, at present, the most prominent mining enterprise in this neighborhood; the Winnebago, on the same lode, and the Argentine, McClellan, Gilpin, and others, in the vicinity, are of growing importance. The Marshall tunnel is also in this hill,

driven in from the mountain side and penetrating the country-rock at a right angle to the general course of the veins, and at such a level as to intersect them at considerable depths.

The Equator lode, located high up the hill-side above the bed of the stream, was discovered in July, 1866. Its course, coinciding nearly with the trend of the hill, is about north 50° or 55° east. The dip is nearly vertical, inclining a little to the north. The north wall is well defined, smooth and regular in course; but the south wall is less clearly marked, making it sometimes difficult to determine the width of the vein. In some places where cross-cut it is said to be 15 feet wide, but the average width, as shown in the greater part of the work, is 4 feet. The filling of the vein is of soft material, consisting chiefly of quartz and feldspar; but it sometimes passes into a harder rock, more granitic in appearance. The ore is galena, zincblende of several varieties, considerable fahlerz, with some ruby silver and native silver. Some of the selected ore is very rich, several tons possessing an average assay value of $1,000 per ton; while the lower grade, which is treated by the amalgamation process, has an assay value of $150, coin, per ton. The extent of development in this mine may be seen by a reference to Fig. 4 on Plate XXXV, which shows the amount of work performed previous to September, 1869. The depth attained is little over 200 feet. The mine has been quite recently provided with hoisting machinery, consisting of an engine, the cylinder of which is 10 inches in diameter by 16 inches stroke. This drives a winding apparatus, of the kind described in the foregoing chapter, consisting of a spool moved by a belt.

The work of mining is comparatively cheap. Drifting costs $7 to $8 per foot; sinking the shaft $30 to $35 per foot. Stoping has been done by the day at $3 50 to $4 per diem. The total production of this mine from the beginning of operations to the end of August, 1869, is about $70,000, coin, or nearly $100,000 in currency, making allowance for the average premium, during that period, on coin value.

This product has been derived about as follows:[1]

| Date. | Tons of ore. | Class. | Average assay value per ton in coin. | Average yield per ton realized by the mine in coin. | Total yield in coin. |
|---|---|---|---|---|---|
| 1868 | *a* 33 | First | ... | $550 00 | $18,150 |
| 1869 | *a* 11 | First | ... | 550 00 | 6,050 |
| 1868 | *b* 113 | Second | $150 26 | 120 16 | 13,978 |
| 1869 | *b* 168 | Second | 146 00 | 116 80 | 19,622 |
| 1869 | *c* 90 | Second | 150 00 | 120 00 | 10,800 |
| | .. | .... | ... | ... | 68,600 |

*a.* Shipped to Newark.
*b.* Worked by Huepeden & Company.
*c.* Worked by J. O. Stewart.

Argentine.—The Argentine district is near the head-waters of the left-hand fork of the stream, and about five miles from Georgetown. This was the scene of exploring work several years ago, and a number of lodes were opened, from which rich ores have been taken, although no very extensive developments have yet been made. The International, Harris, and Belmont are perhaps most developed, and are being opened at present. The characteristic features of these veins are, in many respects, similar to those already described. They are said to carry very rich ore, but the pay-seam is generally small. The mines are at a high altitude. Metallurgical works, consisting of a Dodge crusher, Ball pulverizer, one Brückner cylinder, for chloridizing-roasting, with two Hepburn pans and two barrels, for amalgamation, were in process of construction during the past summer.

The hills that border the valley of the main branch of South Clear Creek, below Georgetown, possess a number of veins that have received more or less development, and some of them are being worked with encouraging results. A description of them, however, would involve the repetition of much that has

[1] According to statements made by Mr. Carpenter, part owner and manager of the mine.

been already said, as the veins of the district are generally of one type, differing chiefly in the richness and quantity of their silver-bearing ores. Among the more important are the Griffith and Summit, on the east side of the stream, and the Cliff, Astor, Beecher, New Boston, and others, on the west side. The first-named strikes north 75° east, dips vertically, and is developed to a depth of about 130 feet. A claim, 300 feet in length, is being worked by the Wilson and Cass Company. About 700 tons of ore had been taken out at the date of the writer's visit, some of which was of excellent quality, the greater part, however, requiring concentration. For this purpose the company had erected dressing works, which will be noticed further on. The Summit, Cliff, and Astor have produced small lots of very rich ore. The New Boston is a large and well-defined lode, carrying a wide seam of galena, which, so far, is not very rich in silver.

TUNNELS.—During the past year some important enterprises have been in progress in the Georgetown district, having for their object the exploration of the country by means of tunnels. The natural features of the region are most favorable to such a method, as the hill-sides are not only very abrupt, but the lodes are generally parallel to each other, and coincide nearly with the trend of the hill, so that a tunnel, driven in from the valley at a right-angle to the general direction of the veins, is likely to intersect several of them in the course of its progress. The tunnel affords, at the same time, the most advantageous method of exploitation, as the vein is worked from below upwards, and the necessity of raising rock and water is obviated. On the right-hand, or west fork of the stream there are three tunnels, including the Terrible, already noticed, which are being driven northerly into Sherman and Brown Mountains. On the left-hand fork is the Marshall tunnel, piercing Leavenworth Mountain, in the neighborhood of the Equator mine, while, in the autumn of 1869, several others were proposed, among them one[1] to enter Leavenworth Mountain from the north side, opposite to the Marshall tunnel, and another to penetrate Columbia Mountain,[2] which lies on the northwest side of the main branch of South Clear Creek, about two miles below Georgetown.

[1] This is now in progress, and is known as the Helmick tunnel.

[2] Also said to be in progress, and known as the Morris tunnel.

The Burleigh tunnel is in Sherman Mountain, a quarter or half-mile east of the Terrible mine. Its mouth is not far above the bed of the stream. It enters the hill on a course of north 15° west, or nearly at a right-angle to the general course of the veins. It is 9½ feet wide and 7½ feet high. In August, 1869, it had been driven 120 feet through hard, granitic, and gneissic rock, without having found anything of value. It has since been driven on continuously, and, according to newspaper reports, has developed some ore-bearing veins. The mountain rises steeply above the tunnel, reaching an altitude at the summit of about 2,000 feet, so that any veins thus cut will be opened at considerable depths below their outcrops. This enterprise is under the management of Mr. Burleigh, the inventor of the drilling machine which bears his name. This machine is employed in the tunnel, and is said to have proved itself here, as elsewhere, a most useful instrument in this kind of work. The details of its construction are too intricate to be intelligibly explained without drawings. It is, however, ingeniously and effectively contrived, performing its duty with comparatively little expense for repair. It is driven by compressed air, which, escaping from the machine at every movement of the drill, affords the great advantage of good ventilation. In the Burleigh tunnel a track is laid, on which a carriage is placed. This vehicle carries four drilling machines, which are so attached to the point of support that they may be fixed at any angle, thus directing the point of the drill against the face of the rock at any desired inclination. The drill strikes 250 blows per minute. When a sufficient number of holes have been drilled the carriage is run out, the holes charged and fired, and the rock thrown aside, so that the carriage may return to the heading; after which the rock is removed from the tunnel.

The air compressors are at the mouth of the tunnel, consisting of two sets, or four air cylinders, 12 inches in diameter by 16 inches in length; and two steam cylinders, 9 inches by 16 inches. There is also a conveniently-arranged machine shop, supplied with necessary appliances for the construction and repair of drilling and other tools. The progress of this tunnel, up to the date referred to, was two feet per day.

The Baltimore tunnel, or, more properly, the tunnel of the National Silver Mining Company, is further up the valley, a half-mile west of the Brown and Terrible mines. It is favorably situated, where the slope of the hill-side

is very abrupt. The tunnel is 8 feet wide and 7 feet high. The rock passed through has been comparatively soft, though granitic in character. At the date just referred to, it had been driven 150 feet, entirely by hand, progressing 2 feet per day, and, according to the best available information, at a cost of $35 per foot. A complete outfit of Burleigh drills, air-compressing machinery, and other appurtenances were on the ground, and about to be set up. A vein, producing galena and zincblende, worth $100 to $200 per ton, had been cut, but not sufficiently developed to afford much knowledge of its character.

The Marshall tunnel, the starting point of which is 50 feet above the bed of Leavenworth Creek, pierces Leavenworth Mountain with a course of north 43° west. It is 7 feet high and 9 feet wide. In August, 1869, it had been driven 320 feet, much of which passed through soft ground. The total cost of driving, entirely by hand, is said by General Marshall, the superintendent, to have been $26 per foot. In the distance then made, several strata, having the appearance of veins, had been cut, but the indications of valuable ore were not so great as to invite further exploration of them at that time, as it was deemed more desirable to hasten on the prosecution of the tunnel as rapidly as possible. Late accounts from the work indicate that the tunnel has now reached a point 700 feet from the mouth, and is in the immediate neighborhood of the Equator lode. According to preliminary surveys this lode should be cut by the tunnel at a depth of 350 feet below the surface.

## SECTION II.

### TREATMENT OF THE ORES.

There are two principal methods by which the ores of this district are treated. One consists in smelting; the other in amalgamation. The first is applied only to ore that is rich in lead, containing not less than 30 per cent. galena, and moderately free from zincblende and gangue. The second is employed for the ores as they more frequently occur, containing a mixture of galena, blende, pyrites, silver sulphurets, and gangue, in variable proportions. The second class is much more abundant than the first, as it is only a small proportion of selected ore that contains the requisite percentage of lead; and much of that which is smelted requires a previous concentration in order to separate the excess of gangue, blende, &c., from that which is suitable for the smelting fnrnace.

There are, in Georgetown and its vicinity, two establishments for the treatment of ores by smelting, one being known as the Georgetown Smelting Works, formerly under the management of Mr. J. T. Herrick, and lately standing idle; the other, located at the Brown mine, and belonging to the Brown Mining Company, as already noticed; three establishments for working ores by amalgamation, the first being that of Messrs. Huepeden & Company, the second that of Mr. J. O. Stewart, and the third that of the Baker Mountain Mining Company. There are also two establishments, lately erected, for the concentration of ganguey ores; one proposing to accomplish the object by dry, the other by wet processes. Besides these are the works of Mr. Dibbin, at Argentine, already noticed, and several smaller concerns, chiefly experimental in their character.

SMELTING WORKS.—The smelting process employed in the first two of the above-named establishments is one of the oldest and best known of all methods for the extraction of silver from its ores, and is described with much detail in various metallurgical works. Its purpose is to smelt argentiferous galena, or other argentiferous substances with lead ores, in order to produce metallic lead in which all, or nearly all, the silver is then contained, and from which it may be separated by cupellation. The details of this process consist

here in the crushing of the ore, the dressing or concentration of that part which is not already sufficiently rich in lead; the roasting or calcining of the charge; the smelting for the production of metallic lead, and, finally, the cupellation, by which fine silver is obtained. The Brown mill is provided with a Blake's rock-breaker for the first crushing of the ores. That portion which is rich enough in lead to be smelted without further concentration is sufficiently reduced by this machine for further treatment; the remainder, which needs to be dressed, is delivered to the stamps. Of these there are 20, weighing 400 to 500 pounds each, falling 10 inches, between 50 and 60 times per minute. The ore is crushed wet and discharged through coarse screens that are made of punched sheet-iron plates. The crushed material is then dressed in a round buddle of the common English form. This is the only means of concentration employed in this mill, and is said by Mr. Watson, the manager, to work very satisfactorily. The ore crushed in the stamps, a large portion of which only contains, on the average, about 20 ounces of silver to the ton, is so concentrated as to yield one ton of dressed ore from six tons of raw material. The dressed product is then mixed with the richer ore of the first class, so that, when ready for further operations, it contains about 200 ounces of silver. The ore is then calcined or roasted, by which process a portion of the sulphur is expelled and a partial oxidation of the metals effected. The furnace for this purpose may be a simple reverberatory, as in the case of the works at Georgetown, or of some other suitable form. The furnace at the Brown mill is a double hearth, or two hearths, one above the other, each 20 or 25 feet long, 10 feet wide, and covered by an arch 15 or 18 inches high. The material is introduced upon the upper hearth at one end, near the stack, and, by means of side doors, is gradually moved along toward the other end, where it drops through to the hearth below, and is then moved, in contrary direction, toward the bridge, where it is discharged. The entire capacity of the furnace is 4 tons per day. Each charge of about one ton requires twenty-four hours to pass through the entire length of the furnace, and one charge is supplied and delivered every six hours.

The smelting furnace employed in both these establishments is the common lead furnace used in England. The hearth is about 11 feet long by 8 feet wide. The charge consists of about 3,000 pounds of roasted ore, which

is made up so as to contain not less than 30 per cent. of lead, and usually a considerably higher percentage. This is mixed with about 10 per cent. of iron and usually about 15 to 20 per cent. of lime. Each charge requires ten or twelve hours' smelting. The molten lead, rich in silver, is drawn off in convenient form for cupellation, while the rich slags are broken up and prepared for resmelting. The lead, when ready for cupelling, contains, on the average, about 2 per cent. of silver. The process of cupellation is performed in an English furnace, and is generally like that already described in chapter VI. Large buttons of fine silver are produced, sometimes weighing 500 or 600 pounds. The actual cost of this work could not be definitely stated. The labor employed costs $4 per day and consists of the following men at the Brown mill: In the dressing works, for twenty-four hours, 2; at the roasting furnace, for twenty-four hours, 2; at the smelting furnace, for twenty-four hours, 6; engineers, 2; sundry jobs, 1.

The capacity of the Georgetown Smelting Works is about the same as that of the Brown mill, and, when running, it employs about the same number of men. While in operation this establishment occasionally worked ores at a stipulated price, about $100 per ton. The usual custom, however, was to purchase the ores of the producer, paying at a fixed rate, according to their assay value. These rates varied, on a graduated scale, from about 30 per cent. of the assay value for ores containing 100 ounces of silver to the ton, to 70 per cent. of the assay value for ores containing 800 ounces of silver to the ton. A condition of this scale requires that the ores shall contain not less than 30 per cent. of galena, and not more than 10 per cent. of gangue nor more than 5 per cent. of zincblende. An excess of zinc or gangue subjected the ores to corresponding deductions.

During the summer of 1869 this establishment had been idle for a considerable period of time, owing, it was said, to financial embarrassments. In the summer of 1868 there were worked about 90 tons of ore, producing 22,134 ounces of fine silver, worth about $28,500.[1] Among the lots of ore producing this amount were the following: 24½ tons from Terrible mine, yielding $510 per ton; 22 tons from Brown mine, yielding $300 per ton; 3 tons from Coin mine, yielding $389 33 per ton.

[1] Statement of Mr. John T. Herrick, superintendent.

Amalgamation Works.—The amalgamation process employed at the metallurgical establishments near Georgetown is the same, in its essential features, as that used in Washoe and the Reese River district, Nevada, for first-class ores. It consists in crushing, chloridizing-roasting, and amalgamating in pans or barrels. In the establishment of Mr. Stewart, a mile below Georgetown, the method of operation in use at Reese River is copied almost exactly. The works of Mr. Huepeden, in Georgetown, possess some distinctive features that will be noticed further on.

Mr. Stewart's mill was built in 1868, and commenced operations in the autumn of that year. It contains 6 stamps of 400 pounds each, which fall 9 inches, 66 times per minute. Its crushing capacity is between 3½ and 5 tons per day, using a screen of 50 meshes to the inch. There are two roasting furnaces, each about 9 feet by 10 in the hearth. These furnaces are constructed generally like that shown on Plate XXIV, and the method of operation is the same as that already described in foregoing chapters. There are two large and two small pans and two settlers, and one retorting furnace.[1]

Mr. Stewart has been almost steadily engaged in working ore by this method since the completion of his works, and finds the method very well adapted to the ores of the district. He receives the ore from the mine and works it at a fixed price, returning to the owner 80 per cent. of its assay value. The charge for working on this basis was $60 per ton of ore, in currency, in 1869.

From November 1, 1868, to August 15, 1869, between 500 and 600 tons of ore, from forty different lodes, had been worked. The assay value of these ores was, on the average, $100, coin, per ton, of which 80 per cent. was obtained and returned to the producer. The total production of the works, during that time, was, therefore, about $45,000, coin.[2]

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[1] According to newspaper report, the capacity of this establishment has been extended during the present year, 1870.

[2] Statement of Mr. John O. Stewart, superintendent.

The following lots of ore were among those making up this product, and will serve to indicate the average value of ores of this class:

| Where from— | No. of tons. | Assay value, in coin, per ton. |
|---|---|---|
| Snowdrift lode | 4 | $191 36 |
| Snowdrift lode | 60 | 80 to 190 00 |
| Equator lode | 90 | 150 00 |
| Terrible lode | 50 | 190 to 240 00 |
| Terrible lode | 2 | 454 00 |
| Baker lode | 12 | 107 90 |
| W. B. Astor lode | 11 | 148 86 |
| Gilpin and McClellan | 40 | 60 to 113 00 |
| Cliff lode | 25 | 150 00 |
| Silver Eagle lode | 3¾ | 289 45 |
| Creek lode | ½ | 912 20 |

Mr. Huepeden's establishment is in the center of Georgetown. It is located on the bank of the creek, from which it derives an excellent water-power. It possesses ample crushing capacity, consisting of 10 stamps, of 600 pounds each, a Dodge crusher, and Ball pulveriser. The last two appliances are chiefly used, the stamps being held in reserve for extraordinary work. The crushed ore is roasted with salt and then amalgamated, the process employed being essentially the same as that just referred to, except that the first operation is performed in Brückner's revolving cylinders and the last in barrels.

Mr. Brückner's cylinder is a contrivance designed to roast ores with salt at a much less cost for manual labor than is involved in the operation of the reverberatory furnace. It is a horizontal cylinder, constructed of iron, usually boiler-plate, and lined with fire-brick. Its form and some of the details of its construction are shown on Plate XXXVI. It is commonly about 11 or 12 feet long and 5 or 6 feet in diameter. It is supported on rollers, *i*, so that it may turn freely when set in motion by the revolving gear, *h*. One end of the cylinder communicates with a brick fireplace, *A*, while the opposite end, *C*, is let into the stack so that the flame from the fireplace passes through the interior of the cylinder. Within the cylinder there is a diaphragm, or partition, running longitudinally through the greater part of its length. This partition is made of iron and covered with fire-proof material.

Fig. 1.

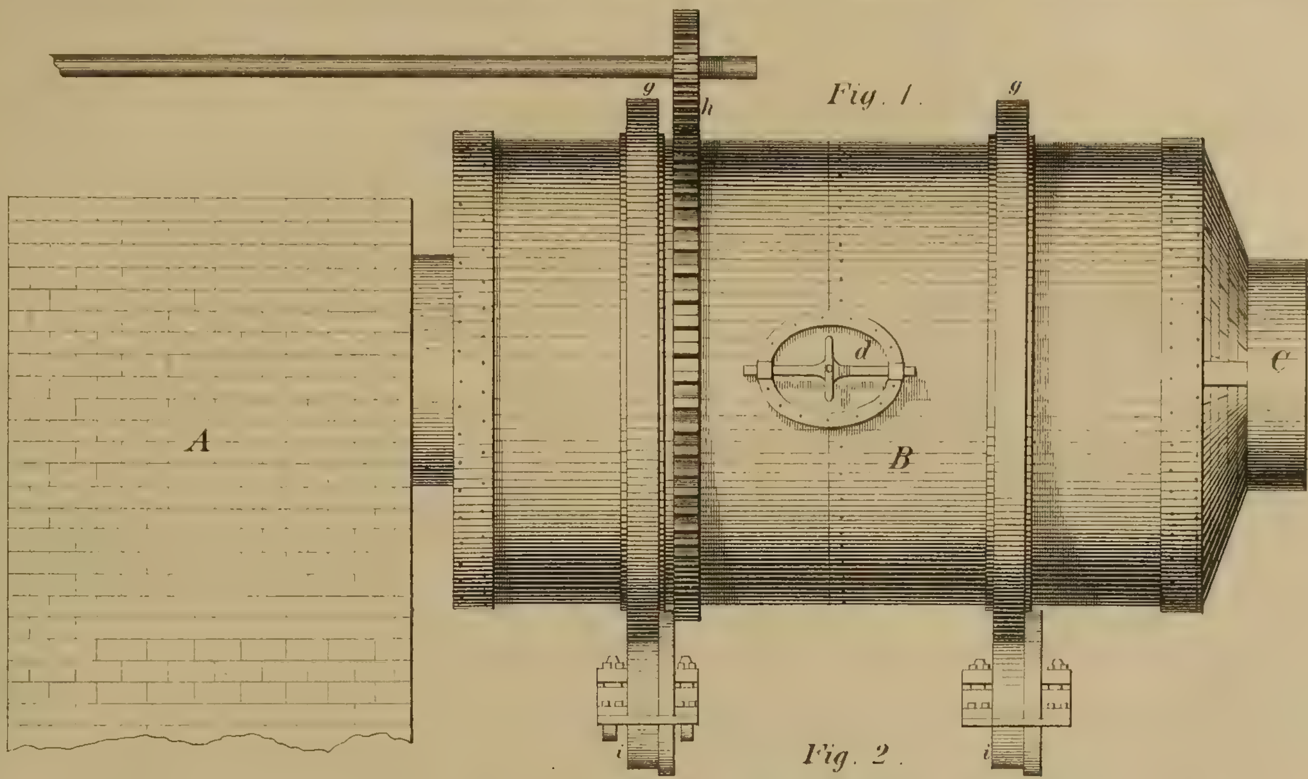



Fig. 2.

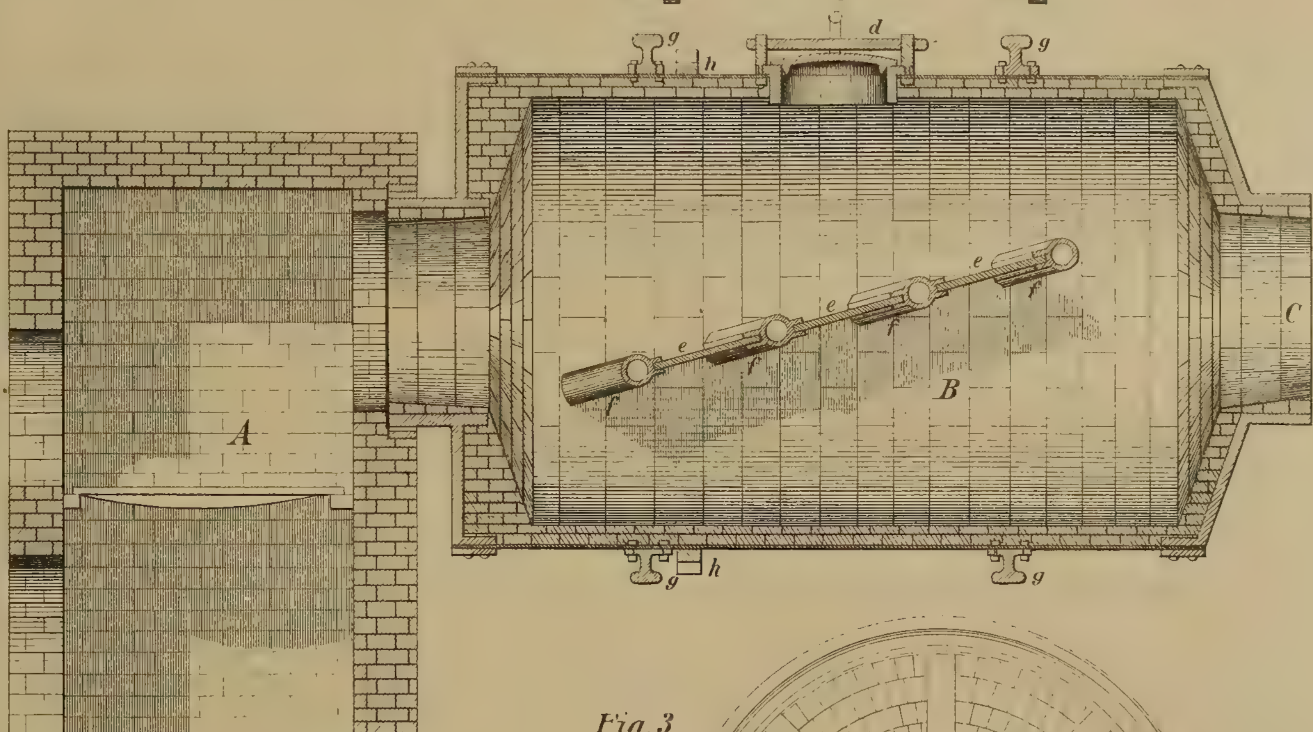
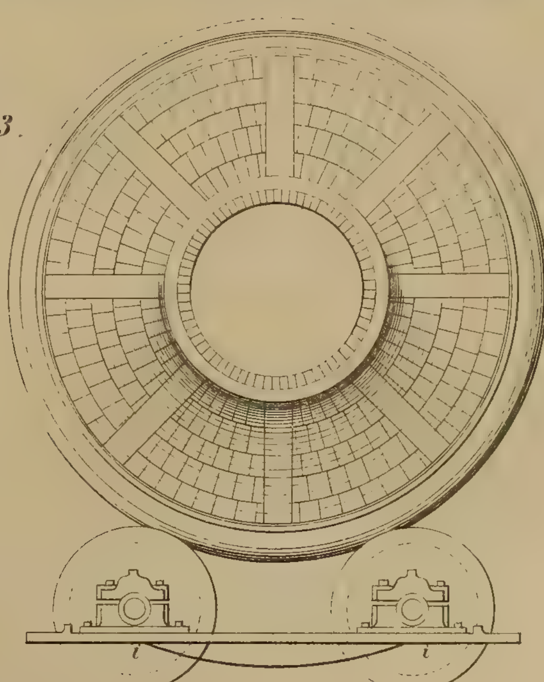



Fig. 3.




Brueckner's Revolving Cylinder.

*A. Fireplace.*
*B. Body of Cylinder.*
*C. End entering Stack.*
*d. Door.*
*e. Section of partition.*
*f. Ribs.*
*g. Flanges or guides.*
*h. Pinion and revolving gear.*
*i. Rollers.*

Scale: $\frac{1}{36}$.

It is usually made in sections, *e*, which are held in grooves that are formed in the ribs, *f*. These ribs are made in tubular form with open ends, which, extending outward beyond the side of the cylinder, permit the passage of air and are thus partially cooled.

When the several sections are in place, the entire partition, or diaphragm, has the form of a rhomb, whose ends are obtuse angles. It is placed at an angle of 10° or 15° with the longitudinal axis of the cylinder, so that as the cylinder, containing a charge of ore, is revolved, the diaphragm causes a continuous passing and repassing of the material from one end to the other and insures at the same time an intimate mixture of the whole mass. A door, *d*, for the charging and discharging of the ore, is placed in the surface of the cylinder opposite the partition. The outside of the cylinder is provided with ribs or flanges, *g*, concentric with the axis of revolution, which rest on the rollers, *i*; also with a toothed rib with which the pinion is placed in gear at *h*, causing the whole to revolve. The fireplace and chimney are built of brick or stone, with funnels large enough for the ends of the cylinder, which may fit into their place easily and revolve. Between the end of the cylinder and the stack there is a dust chamber, in which the fine material that is carried through with the draught may have an opportunity of settling.

The charge of ore for this cylinder consists of 3,000 to 4,000 pounds mixed with from 6 to 10 per cent. of salt. The cylinder revolves slowly, making only one or two turns per minute. It consumes about three-quarters of a cord of wood per day. The chlorination is said to be very thoroughly effected. A detailed statement of the cost of roasting and chlorination was not available, but according to Mr. Huepeden, who has employed these cylinders during two or three years, it is much less than in the reverberatory furnaces. It is probably not far from $6 to $7 per ton.

There are two of these cylinders in Mr. Huepeden's establishment, one of which has been at work two years or more, wearing very well and costing but little for repair.

The amalgamation of the roasted material is performed in barrels, of which there were four in place, and four more were soon to be supplied. The capacity of each barrel was about 2,000 pounds per charge. The details

of this operation do not differ essentially from those observed in Mr. Dall's mill at Washoe, Nevada, already described. Much of the ore treated at this establishment is worked for the stipulated price of $60, currency, per ton, the mill guaranteeing a return of 80 per cent. of the assay value. Sometimes the ores are purchased from the producer at rates which do not differ much in their net result from the foregoing.

The average yield of all ores worked is little over $100, coin, per ton, as will appear from statements following. This is about 80 per cent. of the average assay value. The following figures, furnished by Mr. Huepeden from the books of the establishment, show the average run of ores from several different lodes:

| Name. | Tons. | Worked in— | Assay value in coin per ton. |
|---|---|---|---|
| Equator | 113 | 1868 | $150 26 |
| Equator | 168 | 1869 | 146 00 |
| Lilly | 35 | 1868 | 159 04 |
| Lilly | 9 | 1869 | 145 06 |
| Astor | 28 | 1868 | 165 16 |
| Magnet | 6 | 1868 | 276 70 |
| Baker | 24 | 1868 | 56 89 |
| McClellan | 57 | 1869 | 80 00 |
| Killwinning | 2 | 1869 | 174 00 |
| Terrible | 7 | 1869 | 272 70 |

Mr. Huepeden, the present proprietor of this establishment, commenced operations about the first of May, 1868. The following is his statement of the production of the works from that date to August 15, 1869

| | |
|---|---|
| From May 1, 1868, to December 31, 1868, worked 362 tons of ore, yielding, in coin | $37,465 75 |
| January 1, 1869, to August 15, 1869, worked 352 tons of ore, yielding, in coin | [1] 40,419 31 |
| Total number of tons of ore 714, yielding, in coin | 77,885 06 |

[1] Supplementary statements show that the total production of these works in 1869 was $71,143 50, coin, or about $6,000 per month.

Average yield per ton, \$109 08, coin.

The works produced, under the management of previous owners, Garrett, Martine & Company, about, or a little over, \$20,000,[1] coin, making a total of \$100,000 from their commencement to the date referred to above, a period of something over two years.

Concentration.—The high cost of metallurgical treatment added to that of mining excludes from profitable working a large amount of second or third class ore. The value of this varies from \$20 or \$25 to about \$100 per ton, for with the cost of reduction at \$60, and an available yield of not more than 80 per cent. of the assay value, an ore must contain, under existing conditions, at least 100 ounces of silver per ton, in order to pay all the expenses of mining and milling and leave any margin of profit in the hands of the producer.

Although the veins about Georgetown have produced some very rich ores, it is probable that the amount of ore that can be worked profitably bears but a small proportion to that which must remain unavailable without cheaper methods of reduction. According to a statement on a preceding page, the Terrible mine has produced about 200 tons of ore, yielding \$200 and upward per ton; while the quantity of accumulated ore, of third class, said to be worth about \$80 or \$100 per ton, is estimated at 1,200 or 1,500 tons. A ton of this ore, worth \$80, which may represent the average value of the whole, after paying \$60 for milling, and affording a net yield of 80 per cent., would leave the owners in debt for the expenses of handling, hauling, and other items, including nothing of the costs of mining. If, however, by some suitable and cheap method of concentration, the valuable mineral, or a reasonably large part of it, contained in five or six or more tons of this ore can be brought into one ton, the whole mass may be rendered available for profitable working.

It is probable that the proportion of low-grade ores to those of high value is quite as great as the above, if not much greater, in the majority of the Georgetown veins; and the future prosperity of the district depends very much on the success of the means adopted for concentrating or otherwise rendering available the ores of the lower class; for the business of any mine

[1] From statement furnished by Mr. Charles Martine.

or mining district must remain within narrow limits so long as its operations are restricted to the treatment of first-class ores exclusively.

Within the past year this subject has received much attention in this district, and two establishments have lately been erected for the purpose of concentrating ores of low or moderate value.

One of these, known as the Georgetown Dressing Works, was built and is owned by the Wilson and Cass Company, partly for the purpose of working low-grade ores produced by the mines of the company and partly with the view of purchasing similar ores from the mines of the neighborhood, dressing them so as to separate the valuable mineral from the gangue and shipping the concentrated product to the smelting works of the East. This mill, not quite finished when visited by the writer, is situated a mile or more below Georgetown, near the stream, from which an abundant power is obtained. The process consists of wet-crushing, separating the coarser product on jigging machines of various kinds, and concentrating the fine material on Rittinger tables and other slime-dressing appliances. There are five batteries of stamps, containing five heads each. Each stamp weighs 450 pounds and falls 10 inches 60 times per minute. The screens are made of brass wire and are of different sizes. The first three batteries, through which all the ore must pass, are provided with coarse screens, containing eight square meshes per lineal inch. From these batteries a large portion of the ore escapes in a coarse condition. The crushed material passes thence on to several jigging machines, which, though differing in some details, are, in many respects, like those of Mr. John Collom, that will be described further on. They consist of boxes or tanks that are furnished with sieves of any desired degree of fineness. The ore is carried by the stream of water upon the sieves, and, being kept in agitation by water, the action of which may be understood by referring to the description of Mr. Collom's machine, the heavy ore settles upon the sieve, the finer portion passing through into the box below, while the light, earthy portion of the material or pieces of gangue, still carrying particles of ore, is washed off from the sieve into a sluice or trough in front. By means of this first separation a portion of the clean rich ore, both coarse and fine, is obtained, while the gangue, requiring further treatment, is raised by a simple elevator and delivered to another

battery of stamps to be crushed finer. Thence the stuff issues through screens that have 18 meshes to the lineal inch; passes again to another jigging machine, having a finer sieve than those before employed; the operation being repeated as before, a portion of dressed ore is obtained, the refuse again elevated to the final crushing, where it passes through a screen of 24 meshes, and once more to a still finer sieve, where a third portion of dressed ore is obtained and from which the tailings flow to settling tanks, or other contrivances, which effect a sizing or classification of the material according to its degree of fineness, when it is treated further on slime-tables or in buddles. The capacity of the works is about 50 tons of crude ore per day. They are very well constructed, under the direction of Mr. Julius Kurtz, and are provided with every facility for the prosecution of the work proposed. The addition of other appliances, for the treatment of the dressed products, either by amalgamation or other methods, is contemplated. These works had not entered upon regular operations at the time of the writer's visit, and no definite information has been received concerning their subsequent performance. The following advertised schedule of prices, offered by the company, indicates the advantage which producers of low-grade ores were expecting to derive from the successful working of this establishment:

| | |
|---|---|
| For galena ores assaying $100 per ton, the company pays | $70 00 |
| For galena ores assaying $90 per ton, the company pays | 60 00 |
| For galena ores assaying $80 per ton, the company pays | 50 00 |
| For galena ores assaying $70 per ton, the company pays | 40 00 |
| For galena ores assaying $60 per ton, the company pays | 30 00 |
| For galena ores assaying $50 per ton, the company pays | 22 50 |
| For galena ores assaying $45 per ton, the company pays | 15 00 |
| For those ores in which zincblende predominates— | |
| Assaying $100 per ton, the company pays | $60 00 |
| Assaying $90 per ton, the company pays | 50 00 |
| Assaying $80 per ton, the company pays | 40 00 |
| Assaying $70 per ton, the company pays | 30 00 |
| Assaying $60 per ton, the company pays | 20 00 |
| Assaying $50 per ton, the company pays | 15 00 |
| Assaying $40 per ton, the company pays | 10 00 |

The other establishment designed for concentration is situatea near the town. The machinery intended for its use had not arrived upon the ground when visited by the writer, but some experiments were in progress on a limited scale, which gave encouraging results. It was the purpose of this company to effect the desired separation of gangue from ore by means of Krom's dry concentrator, which involves in its action the same or nearly the same principles as a wet jigging machine, but so contrived that air instead of water is used as the medium in which the material is agitated and separated.

The establishment was to be furnished with a drying furnace in which the ores are first thoroughly dried; a Dodge crusher with rollers to reduce them to a suitable degree of fineness for the action of the concentrator; and three of Krom's machines.

Bullion Product.—The following statement may nearly represent the total production of the Georgetown district up to the middle of August, 1869:

| | Coin value. |
|---|---|
| Georgetown Smelting Works' product estimated at | $55, 000 |
| Mr. Huepeden's Amalgamation Works' product, under the former and present owners | 100, 000 |
| Mr. Stewart's Works' product | 45, 000 |
| Brown Mill product | 45, 000 |
| 100 tons of ore shipped from the Equator and Terrible mines, yielding | 55, 000 |
| | 300, 000 |

The above is believed to show the amount produced during the years 1867, 1868, and part of 1869. Previous to 1867 there were small lots of ore and bullion produced, as the result of experimental operations, the total amount of which would be of comparatively little importance.

Jndging from the operations of the three working establishments during the first part of 1869 the production of the region for that year may be estimated at something between $16,000 and $20,000, coin, per month.

## SECTION III.

### SNAKE RIVER MINES.

The Snake River region lies on the western slope of the range, and is about eighteen or twenty miles from Georgetown. Following up the left hand fork of the stream above that town, and passing through the Argentine district, the road reaches the crest of the range in a distance of about twelve miles, crosses the divide by a pass, a few miles south of Gray's Peak, at an altitude probably of not less than 13,000 feet, and descends on the western side into the valley of the Middle Branch of the Snake River. The region drained by the South, Middle, and North Branches of the Snake River, and their tributary streams, has been the scene of much prospecting and surface exploration during several years. A number of lodes, presenting the general characteristics of those about Georgetown, have been opened and some of them explored to considerable depths. The little settlement of Chihuahua, in the gulch of the same name, lying high up near the summit of Gray's Peak, and that of Peru, in the valley of the Middle Snake, were formerly points that attracted much attention, though both are now deserted. The National Treasury lode, on the Middle Snake, appears to be a well-defined vein, striking north 30° east, true, and dipping 70° to the south. The walls at the outcrop are six feet apart. The vein is filled with a gangue that resembles that of the Georgetown veins, carrying some galena but a great deal of zincblende. A shaft has been sunk on the vein to a depth which could not be ascertained, and some exploration of the lode had been made along the outcrop. The ore of this lode, and of many of the lodes in this region, is of such a character that costly methods of treatment are required for the extraction of the silver, and their development has been suspended to await a time when these facilities may be afforded without long transportation. The region will doubtless invite further work at some future time.

The most active operations, at the present time, are being carried on in the neighborhood of Montezuma, a small settlement on the south fork of the Snake and near the mouth of Bear Creek; and at St. Johns, a mile and a half beyond Montezuma, on the last-named stream. Here several mining

enterprises are in progress. The hill, known as Glacier Mountain, which forms the divide between the South Snake and Bear Creek, has been pretty thoroughly prospected, and a large number of lodes have been opened. Many of these have produced experimental lots of rich ore, and a few have been already developed to such an extent as to prove their value and to invite the investment of a good deal of capital for the equipment of the mining works and the provision of metallurgical facilities.

COMSTOCK.—The best developed and, thus far, most important mine in this neighborhood is that of the Boston Silver Mining Association, opened on the Comstock lode, under the superintendence of Mr. John Collom. This lode is on the west slope of Glacier Mountain, and about 1,000 feet above the bed of the creek at its base. It was discovered in 1865, but a very little work was done upon it during that or the following year. In 1867 more active operations were undertaken; the lode was partially developed, a saw-mill and dwelling houses were erected, and some experimental appliances provided for working the ores. Since that time its development has proceeded gradually, having been interrupted during the winter seasons, owing to the severity of the climate and the difficulty of communication with the sources of supplies, materials, and labor.

Fig. 5, on Plate XXXV, presents a longitudinal section of the mine, showing the extent of its workings in August, 1869. It has been opened entirely by the means of tunnels, to which method the exceedingly steep slope of the hill is admirably adapted. The upper level, reached by a cross-cut tunnel over 100 feet long, is from 60 to 100 feet below the surface, and 300 feet in length on the vein; the lower level, reached by a tunnel 150 feet long, is opened for a distance of 250 feet on the vein, and is 70 feet below the upper level. Some stoping has been done, as indicated in the drawing. From these developments it appears that the course of the lode is about north 15° east, true; its dip is practically vertical, though sometimes inclining a little to the east or west. Its width varies from one to eight feet or more, averaging three feet. Its course is regular, the walls are well defined, and the filling of the vein is remarkably uniform in character. The country-rock is of mixed granitic and gneissic character. The main filling of the fissure, which is usually separated from the walls by a seam of clay, or

"gouge," is a siliceous and feldspathic mixture, not very hard, somewhat broken or cut by seams and clefts, and stained with iron. The pay-seam is from 6 to 12 inches wide, and occurs sometimes on one side, sometimes on the other side of the vein. The ore is chiefly argentiferous galena, two or three varieties of blende, some argentiferous gray copper, sometimes quite rich, some ruby silver, and other rich silver minerals. The gangue minerals, intimately associated with the pay-ore, are heavy spar, quartz, spathic iron, and others of less frequent occurrence. The vein is drusey in character, and vugs, or cavities with crystalline linings, are found often. The pay-mineral appears to occur in bodies, which are continuous for long distances, both horizontally and vertically, so far as known; sometimes, indeed, pinching up to a thin seam, making the vein almost barren, and then expanding to 10 or 12 inches. In one place, on the lower level, a width of over two feet of galena was maintained for a length of 20 or 30 feet. The continuity of the pay-seam, maintaining a fair average width for considerable distances, appears as one of the notable features of this lode. The value of the ores of this vein is often quite high. Selected lots have yielded large returns by assay; the greater part of that which has been worked, however, is first concentrated on dressing machinery, by which means the galena, the blende, and gray copper, with silver sulphurets, are obtained separately. Owing to the absence of suitable smelting or metallurgical works, the last two products, the blende and copper, had remained unworked up to the time of the writer's visit; the galena, or lead mineral, had been smelted, and it appeared that the average value of this dressed mineral was between $150 and $200 per ton.

The ground in the vein is comparatively soft. Drifting costs from $6 to $10 per foot. Stoping, $17 to $20 per fathom. The walls stand well, and the cost for timbering is not great. As the mine is, and for a long time to come may be, worked by tunnels, the actual costs of mining are tolerably light. The ores and rock broken in the mine are brought out to the surface through the tunnels, and there assorted. The poor is thrown away and the workable ore sent below to the mill, by means of a gravity road, lately constructed on the hill-side.

The methods of reduction proposed for the ores of this mine consist of

crushing and concentrating machinery, by which means the valuable mineral is separated from the worthless gangue and prepared for smelting; and furnaces, the object of which is, as at present contemplated, to save not only the silver, but also the lead. During the years 1867 and 1868 some experimental works were erected, containing a number of Scotch hearths, which were used to produce pigs of argentiferous lead, in which form the valuable products of the ore were shipped east for separation. It soon appeared, however, that a larger proportion of the ore, than had at first been supposed, existed in forms poorly adapted to this method of treatment, and the Scotch hearths were therefore abandoned, with the view of erecting furnaces capable of treating the several varieties of lead, zinc, and copper ores that are found in the vein. The construction of these furnaces, at the time of the writer's visit, had just been commenced. The processes to be employed closely resemble those in use at Pont-Gibaud, in France, and Freiberg, in Saxony. They involve the roasting of the dressed mineral, and their subsequent smelting, in such manner as to obtain pigs of lead in which all the silver should be contained. These pigs, thus obtained, will be shipped to Newark, where the separation of the metals may be effected. It is estimated, by Mr. Collom, the manager, that the value of the lead alone will pay the expenses of working, leaving the silver as a profit. As the furnaces were not constructed at the time referred to, a detailed description of the proposed processes is omitted here. They are given at length in several metallurgical treatises.

The concentrating machinery, used for the preliminary dressing of the ore, as a preparation for smelting, comprises two Dodge crushers, a series of Cornish rollers, screens or appliances for sizing the material, and four of Collom's ore-washing machines. The last-named apparatus has been proved by long experience, not only in the district referred to in these pages, but elsewhere in our mining regions, as a most useful and efficient ore dresser. As it is believed to be a machine that may be advantageously introduced into some of our western mining districts in which concentration is yet to become an important feature in the manipulation of ores, a brief description of it is given here.

The drawings on Plate XXXVII show some of the details of the con-

*Fig. 1.*

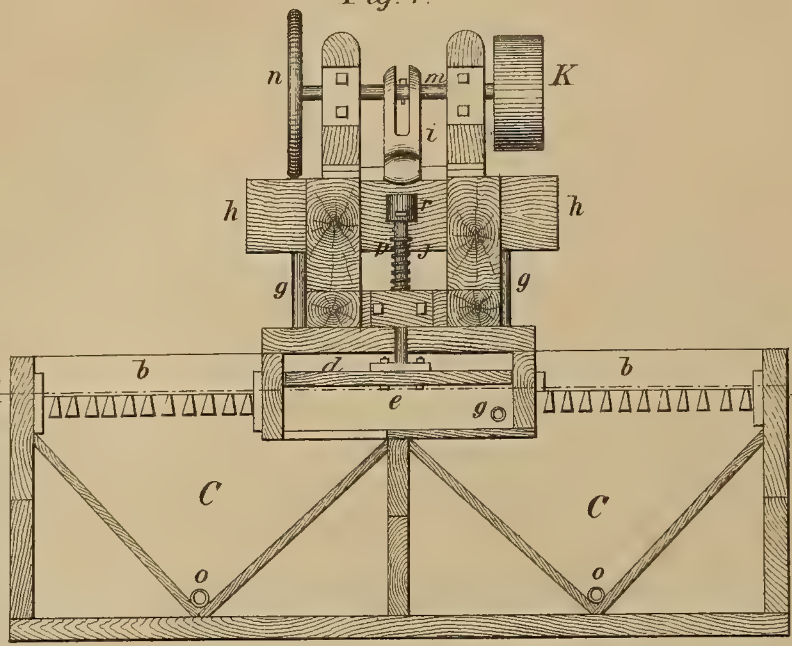



*Fig. 2.*

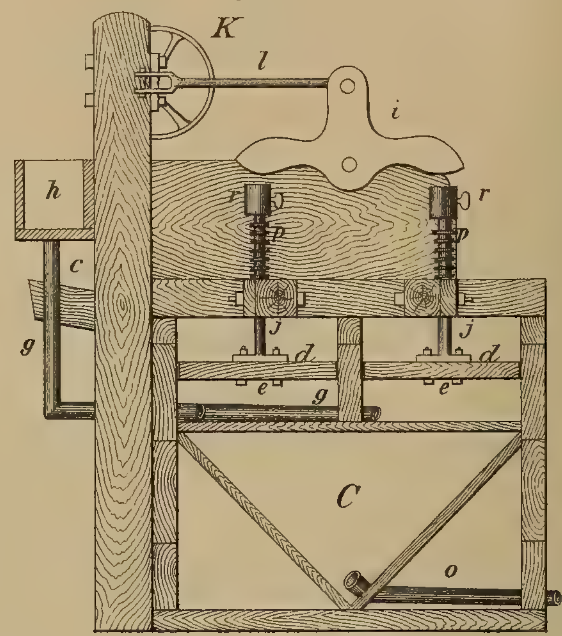



*Fig. 3.*

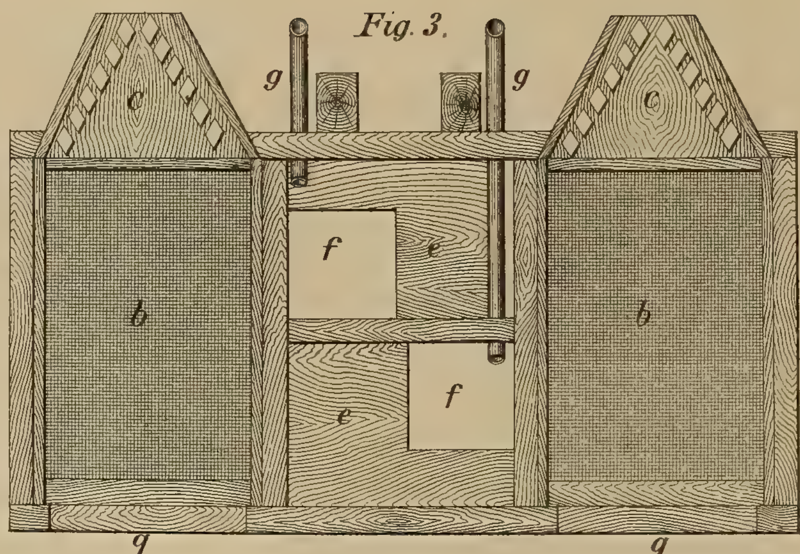
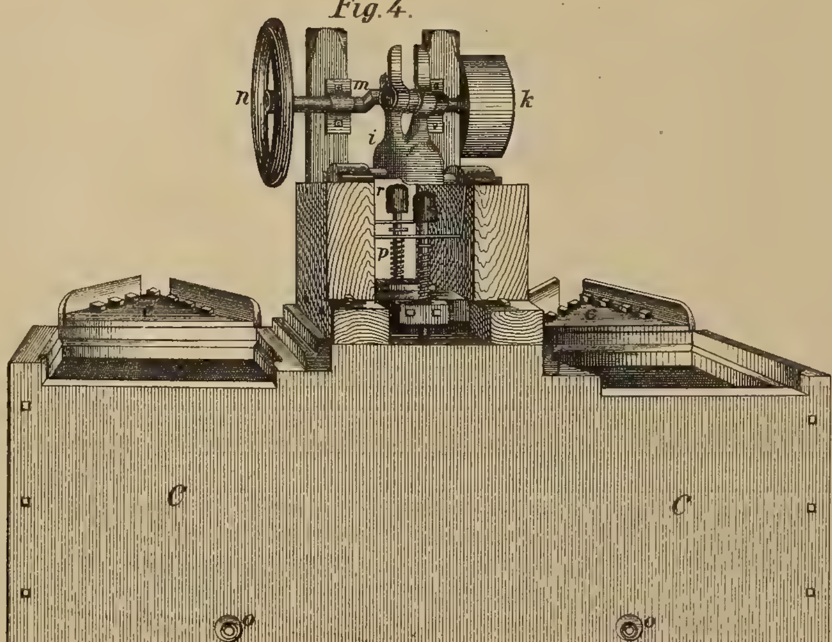



*Fig. 4.*




# JOHN COLLOM'S

## Patent Ore Washing Machine.

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*Fig. 1. Longitudinal Section.*
*Fig. 2. Transverse Section.*
*Fig. 3. Horizontal Section on Line A.B. of Fig. 1.*
*Fig. 4. Perspective View.*
*C. Cistern or Hutch.*
*b. Sieves.*
*c. Buttoned Head.*
*d. Plungers.*
*e. Plunger Case.*
*f. Apertures.*
*g. Water Pipes.*
*h. Water Trough.*
*i. Rockers.*
*j. Plunger Stems.*
*k. Pulley.*
*l. Connecting rod.*
*m. Crank shaft.*
*n. Balance wheel.*
*o. Out-let pipe for ore.*
*p. Springs.*
*q. Overflow for waste sand.*
*r. Adjustable thimbles.*

Scale: $\frac{1}{24}$.

struction of this machine, or, more correctly, of two machines, which, for convenience, are put together as one, though quite independent of each other in their operation. A double machine, like that shown in the drawings, consists of a box or tank, about seven feet long and between three and four feet wide, divided by a middle partition, as shown in Fig. 1, into two parts. Each of these parts is fitted on the inside with inclined partitions, sloping from the four sides toward the center of the box, as shown in Figs. 1 and 2, and thus forming two cisterns, *C*, above each of which is placed a sieve, *b*. The sieve-frame may be furnished with a wire-cloth sieve of any desired degree of fineness, according to the character of the ore to be dressed. Between the two sieves are the piston or plunger-compartments, *e*, separated from each other, and each connecting by an aperture, *f*, with one of the cisterns, *C*. Each aperture, *f*, affords communication with the cistern nearest to it, but without any connection with the other cistern. The plungers, *d*, move up and down in the compartments, *e*, being forced rapidly downward by rockers, *i*, and lifted again by the action of springs, *p*. The rockers are set in motion by pulleys, *k*, with which they are connected by eccentric rods, *l*. The cisterns and plunger-compartments are supplied with water by pipes, *g*, and when the outlets, *o*, are closed the machines are filled with water, the overflow being at *q*, in front of the sieves. The movements of the plungers, therefore, which follow each other in rapid succession, produce an agitation of the water, which rises through the sieves with a constantly throbbing motion. The crushed ores, consisting of heavy mineral and gangue, are brought upon the sieves, *b*, by a stream of water that enters through the distributing boards, *c*, and being subjected to the agitation caused by the plungers, *d*, are held in a state of partial suspension, during which the heavier, metallic particles sink, while the earthy matters rise to the top and are carried off by the water at the overflow, *q*. That portion of the metallic substance which is fine enough to pass the meshes of the sieve falls through into the hutch or cistern, *C*, and may be withdrawn thence at stated intervals by the outlet pipe, *o;* while the coarser part remains upon the sieve and is cleaned up from time to time, leaving a stratum on the sieve for continued operations. The thimbles, *r*, on the plunger rods, *p*, serve to adjust the length of the stroke. The action of these machines is excellent. They effect

the separation of the galena in a very thorough manner from not only the earthy gangue, but from the lighter metallic minerals, such as the zincblende and gray copper. The last two are obtained together, owing to the similarity of their specific gravities, and they are also mingled with heavy spar and some quartz.

The general arrangement of this crushing and concentrating machinery is as follows: The ore is brought upon the receiving floor, where the larger pieces are broken sufficiently to admit the fragments to the crusher. The clean pieces of galena and zincblende are also selected by hand, as far as possible, before the material is sent to the dressing machinery. After passing through the crushers the ore falls upon a screen, furnished with a No. 6 sieve, that is, having six meshes to the lineal inch. Whatever passes over this screen without falling through must be still further reduced in size before going to the washing machines, and passes, therefore, from the screen to a set of Cornish rollers, placed below. The material that falls through the screen enters an elevator and is raised to the sizing sieve, that stands above the washers. The elevator also brings the material delivered from the rollers, still further reduced by them in size, to the same point. The sizing sieve or screen consists of a frame about 6 feet long by 18 inches wide, slightly inclined from one end to the other. The upper end of the frame is fixed on a pivot, while to the lower end is attached a long arm and connecting rod, by means of which a revolving cam raises the lower end of the frame about two inches and lets it drop again upon a fixed support below. The movement is rapid enough to impart a constant jigging motion to the screen and thus to assist the material upon it to slide down over its surface. The upper half of the screen is furnished with a No. 9 sieve, while the lower half has a No. 6 sieve. The material that passes through the first goes to the finer washing machines; that which falls through the second goes to the coarser machines, while all that passes entirely over is returned to the rollers for finer crushing and a repetition of the process. The material then goes to the ore-washers. Of these there are four double machines, or eight sieves. Two of the double machines, containing four sieves, stand on a raised floor, sufficiently elevated above the other two that the material delivered from the outlet pipes, *o*, of the first may flow to the sieves of the second. One of the

upper machines and one of the lower, immediately in front of it, are furnished with No. 6 sieves for washing the coarser material, while the other two, upper and lower, are furnished with No. 10 sieves for the finer stuff. The ore that enters upon the upper sieves is therefore rewashed on the lower sieves, in order to insure a more effective separation. The overflow of the two upper sieves, of either degree of fineness, that is, the material discharged at *q*, is washed again upon one of the lower sieves of the same degree of fineness, the overflow from that sieve being worthless gangue, while that which passes through the sieve is second-quality ore, or blende and copper mixed. The stuff that passes through the two upper sieves, of either degree of fineness, is delivered from the outlet pipes, *o*, and comes upon the remaining sieve of corresponding degree of fineness, the material which passes through that sieve being of first quality, while the overflow, at *q*, is of second quality. By this arrangement there are three products obtained: first, the pure galena, which is almost entirely free from other mineral; second, the zincblende and gray copper, mixed with heavy spar and quartz, almost free from galena; and third, the gangue, which is very clean and free from valuable mineral.

The eight sieves, or four double machines, are capable of treating 20 to 30 tons of ore per day; and as the stuff is all washed twice, the capacity of each double machine, for a single washing, is from 10 to 15 tons per day.

While the Scotch hearths were in use the dressed galena was smelted, yielding about 50 or 60 per cent. of its weight in metal, which was shipped to Newark for the extraction of silver. It contained, on the average, between $300 and $400 per ton. The total shipment from this source amounted to about 10 tons. The costs of transportation were about as follows:

| | |
|---|---|
| Freight to Georgetown, per ton | $20 00 |
| Freight thence to Cheyenne, per ton | 20 00 |
| Freight to Newark, per ton | 37 00 |
| Making in all | 77 00 |

The costs of separation of the silver from the rich lead were stated at $6, making $83, and with lead at 9 cents per pound, or $180 per ton, the balance remaining for costs of mining and reducing was $97 per ton, which, according to Mr. Collom's estimates, based on the experience already gained, would be a sufficient allowance under regular and continuous operation.

None of the second-class ore, the blende and copper mixed, had been worked. Its assay value was between $100 and $200 per ton.

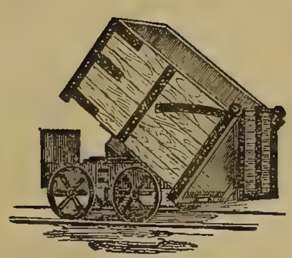
A force of 50 or 60 men has been employed by this company during two or three summers, but during the winter seasons, thus far, their operations on the surface have been suspended altogether and confined to opening the mine with a few men.

There are several other lodes on this slope of the hill that have been opened with much promise, but none of them have yet been developed to the extent of that just described. Among them are the Prima, Potosi, and Coley. The last named had a shaft 40 feet deep, at the time visited, from which a handsome lot of ore had been taken, resembling that of its neighbor, the Comstock, but of which none had then been worked for the account of the mine. A small quantity had been sold to other parties for $100 per ton, of which the yield was not ascertained.

An exploring tunnel has been driven into the hill a half mile from the works of the Comstock, and lower down on the slope, by the Chenango Company, designed to open such lodes as it may intersect. When visited in August, 1869, it had penetrated the country-rock a distance of 400 feet, cutting two or three lodes, neither of which had invited much exploration. This tunnel has since been leased or purchased by the Boston Association with the view of driving it on to the Comstock vein.

The Chenango Company have a small mill, comprising dressing machinery and Scotch hearths, which have been unemployed most of the time since their completion.

In the vicinity of Montezuma, several enterprises of prospective value are in progress. About 50 or 60 men are employed here in various occupations. A number of lodes are being opened, the most developed of which is that worked by Judge Lynch, who is also erecting a mill for the treatment of the ores produced. The general features of the veins are similar to those already described. The works in course of construction are designed to treat the ores by dry crushing, for which there are 10 stamps, roasting in reverberatory furnaces, and amalgamating in Varney pans. A small, experimental smelting furnace is also in operation in this neighborhood. The district is one of growing importance.



# GENERAL INDEX.

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